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An example of an experimental seeding trial for the root parasite *Dactylanthus taylorii*

Avi S. Holzapfel[1] and John Dodgson[2] Return to Contents →

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Abstract

A robust experimental methodology for sowing *Dactylanthus taylorii* seed is used to investigate host species preference, host age, and sowing density. The results from these trials are likely to assist future translocation or restoration of sites with dactylanthus.

1. Objective

To conduct a seeding trial at Waipapa Ecological Area, using a scientifically robust design to allow for comparison between different sowing rates and habitat types

2. Background

Dactylanthus taylorii (pua o te reinga, wae-wae-atua, dactylanthus) is New Zealand's only native fully parasitic flowering plant and the southernmost member of the mainly tropical family of root parasites Balanophoraceae. It lives as a subterranean tuber attached to the root of a number of native tree and shrub host species, which are mainly characteristic of secondary (regrowth) broad-leaved forest (Moore 1940; Ecroyd 1996; Holzapfel 2001; see also King & Atkins 2001 in this volume).

Since work began on the recovery of dactylanthus, cultivation of the species has been one of the primary goals. Successful cultivation would allow for new populations to be established on sites with intensive control of browsing animals, as well as on offshore islands that are completely free of introduced browsing animals. Cultivation of plants would also facilitate future research, public education, and the transfer of established parasite / host associations (*Dactylanthus* Recovery Plan, Objectives 5 & 6 (Ecroyd 1995)).

In 1989 and 1990, seeds of dactylanthus were sown by Chris Ecroyd close to a potential host tree (kohuhu; *Pittosporum tenuifolium*) in a private garden, and onto roots of broadleaf (*Griselinia littoralis*) in planter boxes. The latter plants were later transferred into a forest-like site on the grounds of Forest Research, Rotorua.

In 1998, more than eight years after the last sowing, inflorescences of dactylanthus were observed at both sites for the first time (Ecroyd, report to the *Dactylanthus* Recovery Group 1998, unpublished). While it is possible that plants had flowered unnoticed the year before, these results indicate the long time involved in any cultivation of dactylanthus.

Research on the germination process for the species suggests that after seeds become buried, every year a proportion of the seeds will germinate in suitable conditions (moist soil), regardless of the presence of a host root (Holzapfel 2001). Germinated seeds are able to survive considerable time without attachment, during which time, they attach to a young root growing nearby. A successful attachment to a host root and subsequent infection, therefore seems to depend to a large extent on chance, and will thus in turn be dependant on the density of seeds in the soil.

As no information is available about the number of seeds used in Ecroyd's cultivation experiment, a trial investigating the importance of sowing density would add valuable insight into the optimal procedures for sowing. Conducting the trial at sites with different habitat types will provide additional clues about the importance of habitat and host age.

Experimental seeding trials are currently undertaken in four conservancies (Tongariro/Taupo, Bay of Plenty, East Coast Hawke's Bay and Waikato). The technique described here was developed for trials at Pureora Forest Park (Waikato Conservancy) in 1999, and adopted for trials at Mokoia Island (Bay of Plenty). While the expected long time lag between sowing and flowering does not yet allow assessment of these sowing trials, the technique described here may assist in planning and carrying out further, similar or related experimental seeding trials for dactylanthus. As aspects of the method are generic (such as marking of sowing sites), they may also be adapted to other seeding trials.

3. Methods

SEED SOURCE

Infructescences were collected on 6 January 1999 from different dactylanthus tuber clumps at one site ("Renee's patch", Plains Road) in Pikiariki Ecological Area, Pureora Forest Park. This site is approximately 6km away (straight line) from the sowing trial area at Waipapa. While recent information on the genetic diversity of dactylanthus indicates that proximity is not necessarily a good indicator of population similarity (Faville *et al.* 2000; Holzapfel *et al.* (in prep.)), seeds should be collected from the nearest suitable population, if the sowing site is very close to an existing dactylanthus population.

As seeds are known to remain viable for several years under moist conditions (Ecroyd 1996; Holzapfel 2001), infructescences mostly from the previous year's (1998) flowering season were collected, i.e., seeds were nine to ten months old, or possibly of 1997 vintage, or even older.

A total of 37 infructescences were initially collected, of which 24 with high or medium fruit set (as per *Dactylanthus* Identification and Monitoring sheet (Barkla & Holzapfel 1997)) were selected for the trial. The surplus infructescences were returned to the site of collection on 13 January 1999.

SEED PREPARATION

Seeds, which are generally between 0.8 mm and 1.6 mm in length, were gently removed from inflorescences under running water, and caught in a soil sieve (0.5 mm mesh). Larger particles were removed by running the material through a larger sieve (3.0 mm mesh). Seeds were cleaned by agitating them under water and floating off debris (intact, healthy dactylanthus seeds are heavy and aggregate in water with the sand fraction). The seeds from all 24 infructescences were then mixed, drained over a small tea-sieve, blotted dry through the sieve with paper tissue, and aliquoted into 24 equal aliquot samples by weight on a laboratory scale.

The number of seeds in one randomly chosen sample was counted at 1477 seeds. Ecroyd (1996) found the average number of flowers on a female inflorescence was 3660 where each flower potentially developed into one seed. Therefore, each aliquot sample represented just below half of the average number of seeds expected on a fully pollinated inflorescence. This was regarded as a similar amount as would be expected on an infructescence with medium fruit set.

Seeds were prepared one day prior to sowing, and samples stored individually in plastic petri dishes on moist filter paper. Storage for several weeks was possible in eppendorff vials (250 μl volume, obtained from lab supplies) if the seeds were kept moist. (This was achieved by adding a drop of water to the seeds in the vial before closing).

SOWING SITES

Site selection should take into account that seeds (and probably also tubers) of dactylanthus prefer moist ground.

Four sites were chosen at Waipapa Ecological Area, Pureora Forest Park. All sites are within a radius of just above 1km, and more or less on the same elevation.

Sites 'A' and 'D' are on a slight sloping face, therefore probably more exposed and prone to dryness than sites 'B' and 'C'.

Site A: Has an open canopy, and is dominated by juvenile and adult lancewood (*Pseudopanax crassifolius*), with bracken (*Pteridium esculentum*) undergrowth. The site is somewhat exposed, on a slight slope (with a similar gradient, and close to, site 'D'). It is probably drier than the other sites that have a closed canopy and/or are on level ground.

Site B: Has a closed canopy, dominated by a mix of juvenile and adult lancewood, and an open understorey. The sowing sites were as close to adult lancewood trees as possible.

Site C: Has a closed canopy, dominated by adult kohuhu (*Pittosporum tenuifolium*), and numerous 5-10cm high kohuhu seedlings in the understorey.

Site D: Has a closed canopy, dominated by up to 3m high, adult fivefinger (*Pseudopanax arboreus*). The site is on a slight slope (with a similar gradient to site 'A') and close to site 'A'.

Variables tested in regard to sites are therefore:

- Canopy / exposure: open canopy, more exposed (site 'A') versus closed canopy, less exposed (site 'B'). Both sites are dominated by lancewood.
- Dominant host species: Lancewood (site 'B') versus kohuhu (site 'C') versus fivefinger (site 'D'). All sites have a closed canopy.

At each site three patches suitable for the establishment of two sowing plots were chosen. Sowing plots at each patch were as close to each other as possible, and had to be similar in terms of slope, aspect, distance to the nearest host trees, and type of ground cover. In each patch, two sowing densities (see below) were used; the choice for sowing density in one plot was made by flipping a coin, with the other plot in the same patch receiving the alternative sowing density. Thus, each patch contained one of three replicates for each sowing density per site.

PLOT PREPARATION

A rectangular area of 50×50 cm was marked on the ground with a template made from wire-mesh (5 cm mesh size, 10 mesh across each side). The mesh provided the grid used to sow at exact locations within the plot (Figure 1).

The corners of the template were marked in the ground with permanent aluminium pegs (*c.* 20 cm long) to relocate the exact position of the plot. The grid was laid out according to compass bearing, with the upper side (grid-nos. I1 to I10, cf. Figure 1) facing south. A plot identification number was fixed onto the north-east corner of the grid (grid no. X1, cf. Figure 1.)

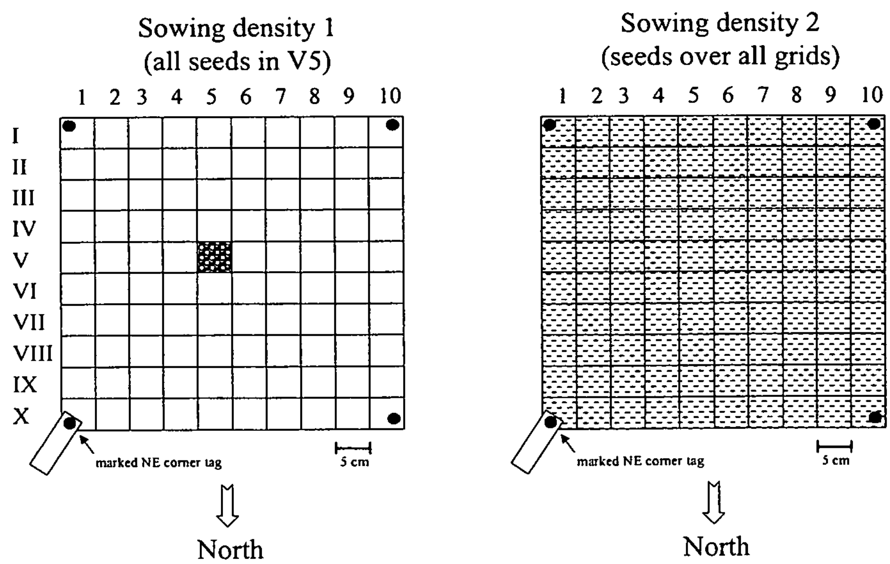
Plot and site localities were recorded as exactly as possible and transferred onto individual recording sheets for each plot, prior to the first monitoring. An example of a recording sheet (developed in excel) is attached as Appendix 1.

SOWING RATES

Two sowing rates were used. (Figure 1.)

1. A single aliquot of seeds, placed in the central grid of the plot. This simulated burial of an isolated infructescence of medium fruit set.
2. A single aliquot of seeds, placed evenly over all grids within the plot. This simulated an even dispersal of individual seeds from one

FIGURE 1: LAYOUT OF SOWING GRID AND PLACEMENT OF SEEDS FOR SOWING DENSITIES 1 AND 2



infructescence over a small area.

Sowing rates 1 and 2 thus have the same number of seeds, but differ in their concentration.

Each sowing rate was replicated three times at each site, bringing a total of six plots per site, and a grand total of 24 plots over all four sites.

SOWING

Sowing was conducted on 12 January 1999. Each aliquot of seeds was mixed with fine dry sand (1 film box = 30cm^3) to facilitate their spread, and sown directly onto the ground after removal of any leaf litter. As the bare ground was tightly compacted at all plots, the soil was broken up to a depth of 5cm prior to sowing to expose living fine roots. It is assumed that dactylanthus infects only young roots, probably at or just above the root-hair section (Moore 1940), thus seeds should be placed close to such roots to optimise infection chances. Leaf litter was replaced after sowing, and the grid removed.

IDENTIFICATION OF PLOTS AND SITES

Three different identification markers were used, i.e.

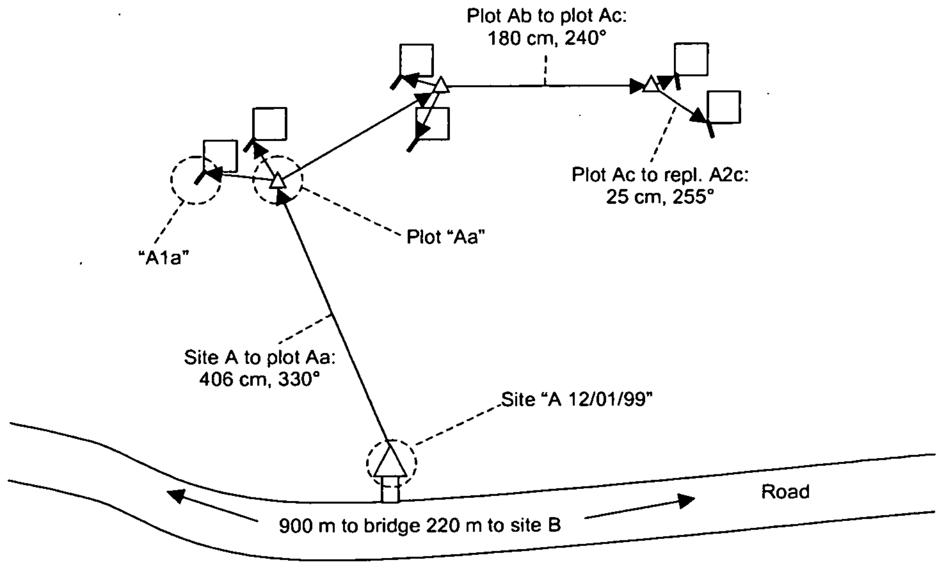
1. **Individual plot markers** for each sowing plot (on the NE corner of each sowing plot)
   Plot markers are small aluminium tags attached on the corner peg (fig. 1). They are stamped with the following code:

   A1a

   The first digit identifies the site (A-D), the second digit identifies the sowing density (1 or 2), and the third digit identifies the replicate number (a-c).
2. **Replicate markers** for each pair of sowing densities (one marker for each replicate pair).
   Replicate markers are triangular plastic track markers, stamped with "Plot", followed by the site code (A-D) in the second line, and the replicate code (a-c) in the third line. Replicate markers are attached to a tree near each plot pair, about 50cm above ground level.
3. **Site markers** for each site A-D.
   Site markers are triangular plastic track markers stamped with "Site", followed by the site code (A-D) and the date (dd/mm/yy). Site markers are attached to prominent trees or wooden stakes.

The distance (metres) and bearing (degrees magnetic) from the site marker to replicate markers, and from replicate markers to the plot marker were recorded, as well as the exact locality of site markers (map reference or GPS reading). In our case, all sites were along the same road, so distance (odometer reading) between each site was also noted. A diagram of each site was prepared from these measurements and taken into the field on each monitoring occasion to facilitate location of the plots, and to check for measurement errors. An example of a site diagram is given below. (Figure 2.)

FIGURE 2: EXAMPLE OF A SITE DIAGRAM. ONLY A SELECTION OF MARKER INSCRIPTIONS, BEARINGS AND DISTANCES IS GIVEN. ALL BEARINGS AND DISTANCES (SOLID ARROWS) WOULD BE RECORDED.



MONITORING

All plots were monitored annually during the time when the nearest populations were flowering.

Yearly monitoring will continue for a period of at least ten years, or until the emergence of dactylanthus occurs. Weekly monitoring over a period of six weeks of all plots is recommended once the first emergence is noted.

Since the trial was initiated, two years of monitoring have been undertaken. Sites, plots and the exact sowing grid position were located without difficulties where the original measurements were correct. Exact measurement, in particular of individual plots, proved to be important as leaf litter had built up at some sites to such an extent that the permanent corner pegs were completely covered.

When monitoring, the plot was carefully examined (visually) for signs of inflorescences or tubers. The original mesh grid was placed over the four permanent corner pegs to pinpoint the exact area of sowing. Disturbance of the soil layer was avoided as much as possible, but leaf litter was sometimes lifted for inspection (and later replaced). The attachment of young seedlings of dactylanthus is known to be extremely fragile, so great care must be exercised when leaf litter is moved.

Other data, such as vegetation within the plot and within the site was collected for every visit. False measurements were noted and corrected, and any missing corner pegs, tags or markers were replaced.

The procedure when an inflorescence or tuber is encountered in a plot will be to note the exact position of the inflorescence or tuber on the recording sheet. The grid will then be removed again.

As it will be important to note the sex of the emerging inflorescences, cages will be placed over the plots as soon as emergence is observed, or when the soil becomes visibly scratched by browsers. Cages will not be placed over the plots from the beginning of the trial, because of the recent history of thefts of dactylanthus plants in the area. At other sites where collection is less of a problem, caging the plots from the beginning of the trial will minimise loss of inflorescences before they can be detected.

DATA ANALYSIS

The data will be analysed in several ways to compare between sites and between sowing rates. For the analysis, results for all three replicates for each sowing rate on one site will be combined, and the mean result used in the analysis.

The following parameters will be used in the analysis:

- Mean number of plants per plot per sowing rate
- Position of plants in the plot
- Size of the tubers (if feasible)
- Sex of the plants
- Time of first emergence
- Sequence of emergence (if more than one plant is found over the whole monitoring period).

Intensive monitoring will largely cease when no new plants are found, but general monitoring will be carried out annually to record changes in the number of inflorescences per plant, their sex, and the size and shape of the tubers.

4. Conclusions

The method described here provides a robust experimental design for sowing dactylanthus seeds, and tests the importance of three variables (host species, host age and sowing density). These variables can be exchanged for different variables (e.g., slope or aspect) in other experiments, however, if the total number of variables is to be increased, then the number of replicated plots must also be increased accordingly, so that a minimum of three replicates per variable combination is maintained. The present method facilitates long-term monitoring (ten years) of the exact area where seeds have been sown. This is of particular importance because of the cryptic habit of dactylanthus, which otherwise would make confirmation of plant establishment very difficult. It is hoped that results from these trials will assist future translocations or restoration of sites with dactylanthus.

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APPENDIX 1: MONITORING SHEET FOR DACTYLANTHUS SEEDING TRIAL

***Dactylanthus taylorii* sowing trial, Waipapa Ecological Area, commenced 12 January 1999. Plot sheets**

Site	Site marker locality	Site description	Plot replicate	Replicate marker locality	Replicate description	Plot	Plot marker locality	Sowing rate	Notes 2000
A	2990m after crossing of bridge, 400m past site C, 500m before site A. Site marker on middle stem of triple-stemmed, mature lancewood, visible from the road. Distance from road 6m, bearing 160° true.	Dominated by juvenile and adult lancewood, with bracken and *Blechnum* undergrowth. Open canopy. Site somewhat exposed on a slight slope (same slope as, and close to, site D), therefore probably drier than remaining sites with closed canopy and / or on level ground.	Aa	170°, 2m from site marker.	Ground dry, only slightly scarred before sowing, covered back mainly with leaf litter.	A1a	15cm, 220° from Aa.	1	Moist fern and toi-toi leaf-litter. Pegs OK. No sign of *Dactylanthus.*
						A2a	190cm, 140° from Aa.	2	Moist fern and toi-toi leaf-litter. Pegs OK. No sign of *Dactylanthus*
	Overall for site A: No disturbance noticeable during 2000 visit.		Ab	5m, 120° from Aa to Ab. 250°, 720cm from site marker A to Ab. Above plot marker A1b	Ground dry, some moisture (coolness), ground scarred to about 2.5cm depth, covered with soil and leaf litter after sowing	A1b	50°, 5cm from Ab.	1	Not much leaf-litter apart from some lancewood and fern fronds. Pegs OK. No sign of *Dactylanthus.*
						A2b	16°, 30cm from Ab. 195°, 110cm from plot marker A1b.	2	More leaf-litter than A2a. Pegs OK. No sign of *Dactylanthus.*
			Ac	120°, 80cm from Ab.	Ground drier than in replicate b, scarred to about 3cm depth, covered as in replicate b.	A1c	220°, 20cm from Ac. 325°, 310cm from plot marker A1b.	1	Some more leaf-litter than A2a (little *Blechnum*). Pegs OK. No sign of *Dactylanthus.*
						A2c	40°, 140cm from Ac. 230°, 200cm from plot marker A1c.	2	Very little leaf-litter. Pegs OK. No sign of Dactylanthus.

Note: distances and bearings have been changed from the original to protect site identity.

A new survey technique for the root parasite *Dactylanthus taylorii*

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Abstract

A new field survey method for *Dactylanthus taylorii* uses the dietary preference of possums for dactylanthus inflorescences. This method greatly increases the chance of finding dactylanthus during the flowering period in possum-inhabited areas, by utilising standard possum cyanide or trap-line methodology, terminating the possum, and inspecting the stomach contents. When possums have eaten dactylanthus inflorescences, a characteristic purple staining is present in the stomach contents.

The incidence of dactylanthus evidence in the possum gut corresponds to the positive presence of dactylanthus plants in the immediate vicinity, in an approximate area of up to ·100m from the capture site. A more intensive search can be then undertaken to locate plants when time becomes available.

The method is fast and can either be undertaken concurrently with possum control operations or specifically as a stand-alone dactylanthus survey methodology.

The characteristic dactylanthus staining and inflorescence bracts have also been found in the stomachs of pigs and ship rats. Dactylanthus bracts can also be found in excreted possum faecal pellets and are more persistent in the environment in this form.

1. Introduction

The endemic root parasite *Dactylanthus taylorii* (dactylanthus, Pua o te Reinga) comprises a subterranean tuber attached to a host root causing the root to develop the characteristic "wood rose". The tuber itself is generally a dark coloured woody lump with a more or less "warty" appearance. The 'warts' comprise the attachment points of flower stems from past flowering.

During late summer and autumn dactylanthus inflorescence buds emerge from the soil above the submerged tuber or around exposed plants. Dactylanthus inflorescences (often simplistically referred to as "flowers") comprise of 10-20 erect, 20mm high finger-like stalks (spadices) covered in minute flowers. Stiff bracts sheath the stem as well as enclose each inflorescence bud and cup the spadices when the inflorescences are fully open.

Dactylanthus is currently known to have a patchy distribution, roughly centred on the central North Island, with outlying populations in Northland, the Waikato, the Rangitikei Valley, East Cape, and one off shore island. Historically the plant had a far wider distribution including, in living memory, the Wellington Region, and possibly also the north-western part of the South Island. Fossilised pollen records show a previous distribution over the entire length of both main islands and Great Barrier Island.

The reduction in the plants distribution and abundance is attributed to forest clearance for farmland, over collection in the past, and the ongoing impacts of possums eating inflorescences and thus preventing seed–set. More detail on aspects of its ecology, threats, and management is provided in Ecroyd (1995, and 1996). Dactylanthus is ranked a Category "A" threatened species for conservation management (Molloy and Davis 1994) and "Conservation Dependent" in de Lange *et al.* (1999).

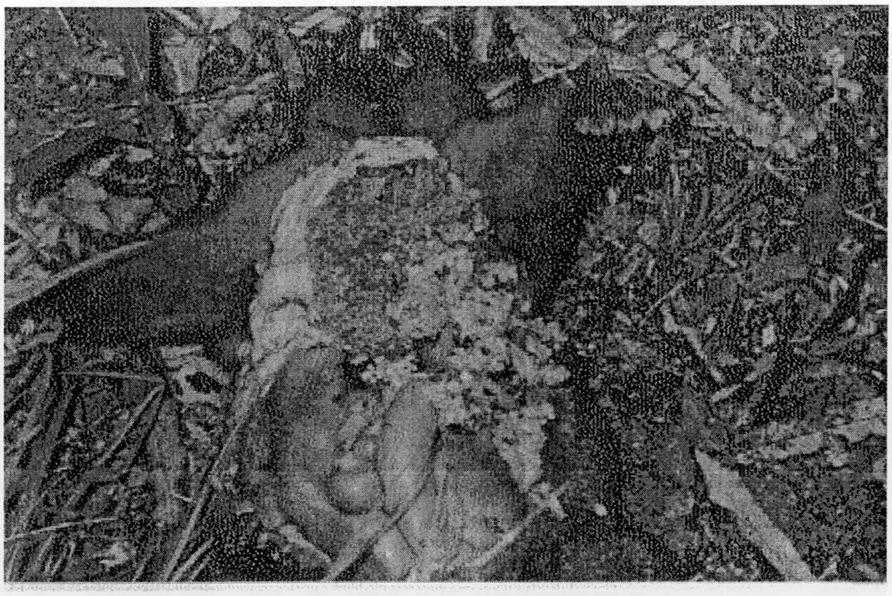
Objective 4 of the dactylanthus recovery plan (Ecroyd 1995) is "to obtain better information on the current distribution of *Dactylanthus taylorii*." The plan recommends that in the first instance, historical records are referred-to, to determine priority sites for survey.

Dactylanthus survey in the past has relied on visually locating tubers where they are exposed through erosion, trampling, or possum excavation and browse. Dactylanthus are difficult to survey and detect at a new site because of their often-localised distribution, their occurrence within difficult vegetation-covered sites and the subterranean nature of the tubers. The new method alleviates some of these difficulties.

2. Survey method

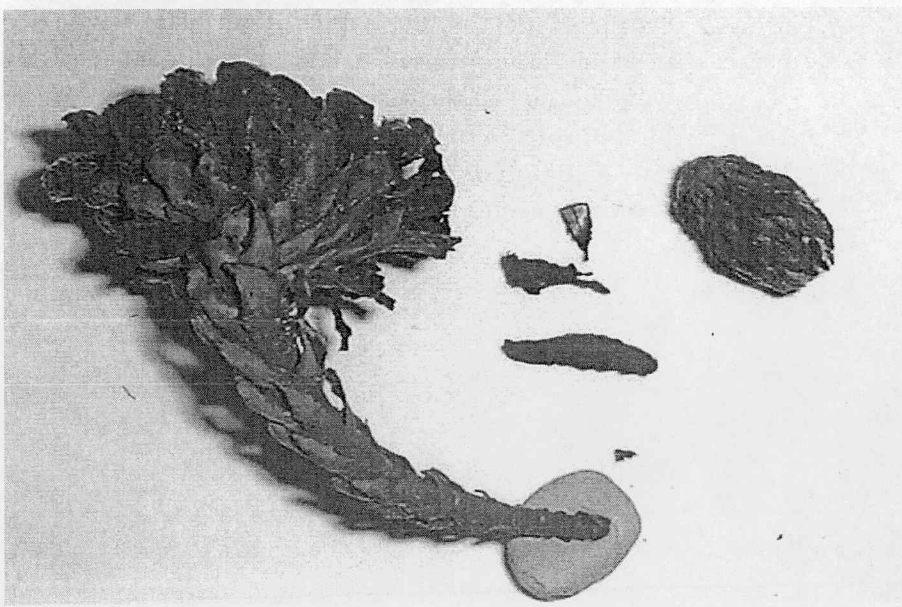
Once an area has be chosen for survey, based for example on an historical record, the surveyor then targets areas of suitable dactylanthus habitat for the location of a cyanide or trap lines - whichever is the most appropriate method to capture possums. Suitable areas are usually dominated by secondary hardwood species that include the prime hosts for dactylanthus. Ecroyd (1995) lists 32 host species in the dactylanthus recovery plan. Dactylanthus is found usually within forests with a history of disturbance

FIGURE 1. OPENED POSSUM STOMACH SHOWING BOTH STAINED (AT TOP) AND NON-STAINED MATERIAL (BELOW RIGHT).



Bract identification can be difficult. The bracts (or scales) are dark brown, thin, somewhat translucent, and hard, but flexible (Figures 2 & 3). Margins, in some instances are paler, but can be darkened. There are often lighter brown patches either side of the mid-line. The bracts pass right through the possum's digestive tract without being digested, and usually remain very obvious in their pellets. If possums eat the dactylanthus buds before they are fully open, then only the bracts might be present without the purple staining.

FIGURE 2. FEMALE DACTYLANTHUS INFLORESCENCE SHOWING BRACTS SHEATHING THE STEM AND HEAD (LEFT) SOME DETACHED BRACTS (CENTRE) AND AN UNOPENED BUD (RIGHT).



through logging, fires or slips where such host species are now more common.

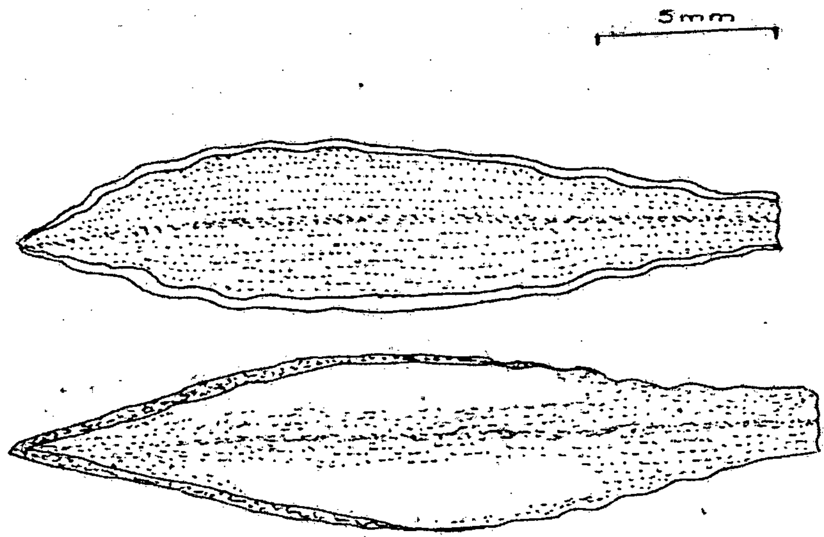
The timing of the survey is very important and should coincide with the peak of the flowering period. Reference to the flowering period of the nearest monitored dactylanthus population should be made to determine the optimum survey time.

The cyanide (or trap) line is run out in accordance with the standard methodology (Warburton 1997), however the line may only need to be open for one night. Traps should be individually numbered and the exact locality of each trap recorded (with a grid reference, local map or GPS reading), as this will facilitate the location of the same site for further surveys. Undisturbed cyanide baits should be destroyed or neutralised when the line is checked and removed. Possum leg-hold traps can also be used, but the advantages of using cyanide lie in the speed of the knockdown, as longer lines can be run with a reduced chance of the possum digesting or excreting its stomach contents during the night. A disadvantage of using cyanide, compared with trapping, is the department's requirement to prepare an Assessment of Environmental Effects beforehand.

All possums caught are first terminated and their stomachs opened, either on site, or off-site once the exact trap locality has been recorded. A single knife-cut across the base of the ribcage is sufficient to open the gut cavity and stomach. In general, the stomach contents of possums will reflect the night's feeding without significant digestion, and the stomach contents can be inspected for dactylanthus remains.

Gut contents are then inspected for the signs of dactylanthus, namely staining and chewed up inflorescence bracts. Dactylanthus nectar stains the stomach contents of possums a bright pink-purple colour (Figure 1). The degree of staining depends on the quantity of dactylanthus eaten, as well as the time since it was eaten. If a possum has ingested a large quantity of dactylanthus all the stomach contents and the stomach walls will be stained a pink-purple colour. If only a small amount of dactylanthus has been ingested, only a slight coloration may be evident. The presence of inflorescence bracts is often a useful additional confirmation in these cases.

FIGURE 3. COMMON SHAPES AND MARKINGS OF DACTYLANTHUS BRACTS. BRACTS ARE USUALLY STRONGLY CURVED (ALONG A VARIETY OF PLANES SEE FIGURE 2) AND RUSSET-RED IN COLOUR.



Fruits of other plant species such as tutu (*Coriaria* spp.), miro (*Prumnopitys ferruginea*) and *Coprosma* spp. can also stain the gut a similar colour. Where bracts are absent from the stomach contents, a small sample may have to be examined under a stereo microscope for the presence of individual dactylanthus flowers. Where identification remains unconfirmed (fern-scales are somewhat similar to dactylanthus bracts), members of the dactylanthus recovery group are best contacted to identify staff who can assist. If assistance is being sought gut samples are best frozen as soon as possible and sent away frozen.

SEARCHING THE SITE AFTER FINDING POSITIVE PROOF

The identification of dactylanthus within a possum stomach is followed-up by searching the immediate vicinity for the dactylanthus plants (Jones 1995). In general dactylanthus is found within approximately a 100-metre radius of the positive carcass. At Te Araroa this distance was often shorter, generally within a 50-metre radius.

Even though dactylanthus occurs on a large range of host species it is commonly found on a few preferred species at a particular site. Searching for these preferred host species is often quick and successful. The surveyor may also be able to narrow the search further by looking for bait or lures that have been interfered with on either side of the toxic one that killed the possum. This would give an indication of the direction the possum was travelling in, subsequent to eating the dactylanthus and prior to poisoning. At Te Araroa, using a trained fox terrier to follow the scent trail of the possum directly back to its last dactylanthus meal has further refined searching.

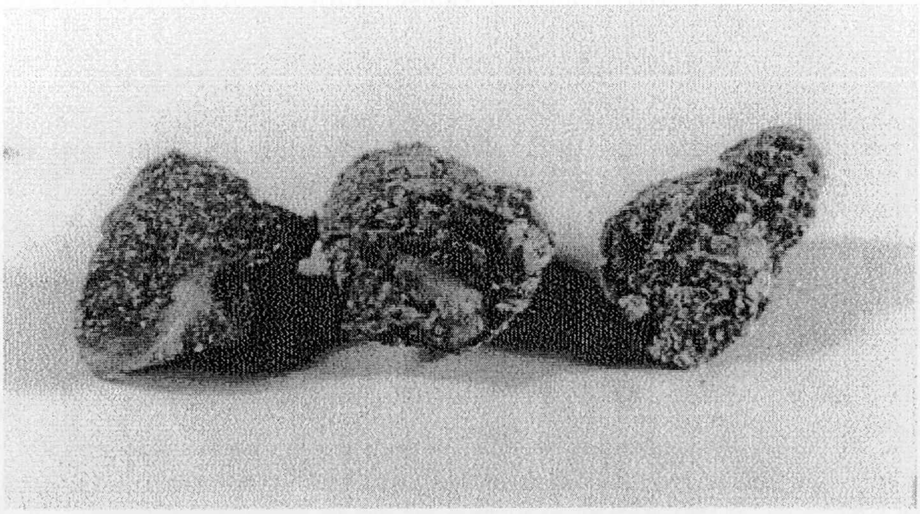
ASSESSMENT OF DACTYLANTHUS ABUNDANCE

As well as confirming dactylanthus presence/absence we believe that this methodology can provide a rough estimate of dactylanthus abundance, based on the observation that dactylanthus is a preferred food source for possums. Possums will choose to eat dactylanthus in preference to any other food sources available at the time. Therefore a large amount of dactylanthus evident in a number of possums indicates a large population of flowering dactylanthus in the local environment.

DACTYLANTHUS IN POSSUM FAECAL PELLETS

Dactylanthus bracts can also be found in possum pellets (Figure 4). Intact bracts within a possum pellet often forms a plane of weakness so that the pellet tends to break at this point. The bracts are generally easy to recognise though occasionally they are finely macerated and are no longer distinctive. Although occurring in fresh pellets during the dactylanthus flowering season, pellets with dactylanthus bracts may persist in dry sites for many months. Lone wilding pines are particularly preferred as possum roost-sites and the dry acidic litter beneath them can preserve possum pellets for up to a year. The persistence of pellets in this environment allows dactylanthus presence to be surveying for well past the end of flowering, and thus beyond the time possum guts will be carrying dactylanthus stain, or bracts.

FIGURE 4. EMBEDDED DACTYLANTHUS BRACTS IN THREE POSSUM PELLETS.



USEFULNESS OF OTHER ANIMAL PEST SPECIES FOR DETECTING DACTYLANTHUS

Possums have been the focus of attention in the development of the method to date because of their relative abundance and reliable methods for catching them, however other species such as pigs and rats might also be used.

In the dactylanthus-dense area at Te Araroa three pigs have been caught with large quantities of dactylanthus material in their stomachs. However pigs are unlikely to provide more than a confirmation of the presence of dactylanthus in the general area because of the distance they can range over a night.

Ship rats will eat dactylanthus flowers and show stained stomachs and stomach contents, but will often macerate the bracts too finely for easy identification. Microscopic examination might still confirm the presence of dactylanthus flowers in stomach contents.

3. Conclusions

This dactylanthus survey method is an efficient and effective tool for finding dactylanthus plants. It is a far more efficient use of time resources compared with 'walk-through' surveys alone (Jones 1995), and should be combined with those. An advantage of this method is that it can be easily applied to programmed possum control operations for forest habitat protection during the dactylanthus flowering period (February to June depending on geographic location). This method has been implemented over recent years at a variety of sites and has assisted in locating several new populations (Department of Conservation 1999; 2000; Atkins 2000).

This method can be used by other possum contractors (e.g. Regional Councils, WAM teams, possum fur trappers) willing to assist the department in the search for dactylanthus. A fact-sheet aimed at introducing non-departmental possum contractors to this method has been circulated to conservancies with current and historic records of dactylanthus. The document is available through the department (and through the following links: HWKCO-4220 and HWKCO-16597).

The strength of the this new survey method is that it uses the principal agent causing the decline of dactylanthus to quickly and effectively find populations for protection. It enables surveys over a much larger area than previously possible, and should therefore be particularly useful to investigate the presence of dactylanthus at sites with existing historic records, such as the Wellington and Nelson-Marlborough regions and, with modifications (rats instead of possums), possibly Great Barrier island.

Acknowledgements

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Mohua on Mt Stokes, Marlborough Sounds, northern South Island – the rise and fall of a population

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Abstract

A small relict population of mohua (*Mohoua ochrocephala*, yellowhead) was discovered on Mt Stokes, Marlborough Sounds in 1985. This represented the only extant population north of the Hurunui catchment, in Canterbury. Subsequent work showed that there were about six pairs and that they were confined to silver beech (*Nothofagus menziesii*) forest along a 7km length of the Mt Kiwi - Mt Stokes - McMahon massif above an altitude of 1000m. Since that time, the area has been a focus for relatively intensive control of pest animals with a view to not only preserving the mohua, but also *Powelliphanta* snails and botanical values.

Stoat trapping and physical protection of nests occurred in most years, and was regarded as being effective management of the mohua population, as numbers gradually increased up until 1999, when there were in excess of 90 birds present. During 1999 and 2000 numbers decreased to the point where no birds could be located in December 2000. The demise of this population was attributed, in part, to an increase in numbers of ship rat (*Rattus rattus*).

Four birds were translocated from Mt Stokes to the rat-free island of Nukuwaiata in November 1999. The extinction of a vertebrate population is rare, and it is hoped that in this case there is sufficient information to explain why it occurred and what lessons may learnt for future species management in beech forests.

HISTORY OF MANAGEMENT

Mohua disappeared from most forests in Nelson and Marlborough during a period of 50 years (Gaze 1985) in which they went from being one of the most common bush birds (Moncreiff 1925) to the least common. This decline is attributed to a loss of the preferred fertile red beech forests and an increase in mammalian predators, to which hole-nesting birds such as the mohua are particularly prone. The reasons for mohua surviving on Mt Stokes after they had disappeared from all adjacent beech forest are regarded as being a combination of low predator numbers at this altitude and a lack of beech honeydew and the associated wasp numbers which would compete for invertebrate food (Elliott 1990).

The rediscovered population on Mt Stokes was regarded as being both valuable and vulnerable given its isolation and small size. Table 1 summarises mohua and pest numbers.

TABLE 1. ANNUAL CHANGES IN THE NUMBER OF MOHUA PRESENT AND THE NUMBER OF PREDATORS TRAPPED.

Year	85	86	87	88	89	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01
mohua (numbers)	5	11	5	1	3	11	5	10?	15	25	25	44	66	90	20	0
stoat (numbers)						3	9	7	4	3	46	19	11	13	87	24
weasel (numbers)						0	0	0	0	0	5	0	0	1	15	1
rat (numbers)						0	0	0	0	0	0	0	1	0	30	26
mice/120TN											12	1	0	1	6	

Beech seeding events (arrows at 96/97 and 00/01)

Note: The mohua counts were usually made at the end of the breeding season and included fledglings, which are subject to differing search efforts between years. Predator numbers usually relate to those caught from October to March but are subject to different trap efforts between years. The 1999/00 predator figures relate to Nov-Jan (incl.) only. The mouse index was taken in December and indicative of beech seeding the previous autumn.

1986/87

A 6.5km transect was walked in November from Kiwi to Okoha Ridge, and detected two-three pairs in each year.

1988

Only one bird was recorded over the same transect.

1989

The transect was extended to include the ridge south to McMahon and taped calls were used. This transect was done in October and repeated in late November. Only three birds were seen just north of Mt Stokes, and only on the October trip.

1990/91

Elliott (1990) recommended management options for the population, and as a result a bivvy was flown onto Mt Stokes, and 17 Fenn traps were initially installed there. This number was increased to 27 by March 1991.

Brown (1991 unpublished) reported a decline in mohua numbers from 1985 to 1990, and an increase over the 1990/91 season to nine adults and at least two fledglings. Nineteen person-days were spent monitoring the Mt Stokes site over this season. The data collected established that this population breeds later than other populations (e.g., Fiordland where there is only time for one brood per year), and that the song is distinct.

1991/92

Seedfall was also monitored, as it was decided that this may be a predictor of stoat irruptions. Only two pairs of mohua were located, and one fledgling was produced.

1992/93

At least four mohua pairs were detected this season, producing three or more fledglings. A recovery plan for the species was published (O'Donnell 1993).

1993/94

Five mohua pairs produced five fledglings. Low numbers of stoats were observed.

1994/95

Eight fledglings were raised from three breeding groups. The season ended with at least 25 birds present including some recorded to the south of Mt Stokes for the first time. This season began with 46 Fenn traps, which were increased to 50. Only three stoats were caught in this season, between October and April. All known nests were protected with additional traps and aluminium bands placed around the trunks of trees with active nest-holes.

Beech trees were observed to be seeding which lead to a prediction that more stoats may be present in the next season.

1995/96

The project received additional funding which allowed greater trapping effort. The number of Fenn traps was increased to 112. These were placed mostly on perimeter tracks, and formed a barrier to stoats dispersing into the core (200ha) mohua area. Stoat predictions were well founded, as 42 stoats and five weasels were caught up until February. This catch amounted to 0.15 animals per 100 trap nights compared with an average of 0.05 per 100 trap nights in other years. There was no evidence of predation at any of the three known nests. Total numbers of mohua were similar to the last year.

1996/97

Other areas of likely habitat in the Marlborough Sounds were searched for mohua without success.

A good year on Mt Stokes saw *c.* 30 adults fledging, and at least 14 young. Nineteen stoats were trapped.

1997/98

This was another good year, with 36 adults starting the season. There were 14 pairs, of which ten were successful breeders, and managed to fledge 30 young. Nine of the ten known nests were protected by metal bands, and all had additional traps situated nearby. (Two stoats were caught in these additional traps.) Total mohua present on Mt Stokes at March 1998 equalled 66.

Long-tailed cuckoo parasitism was observed for the first time on Mt Stokes.

Only 11 stoats were caught during this season. A single ship rat was also caught, which represented the first in seven years of trapping.

The management of mohua at Mt Stokes was seen as more effective than at any of the other South Island sites. This may have been due to stoat trapping in all seasons rather than just during mast years.

1998/99

The season ended with a total of 90 birds consisting of 51 adults and 39 fledglings. This season was another masting year, and ended with heavy beech seeding. Thirteen stoats were trapped between October and March.

1999/2000

Plans were approved for the translocation of some mohua from Mt Stokes to Nukuwaiata this season. The operation was endorsed by the recovery group and timed to precede an expected increase in predators following the heavy beech seeding during the previous autumn. Three adult males and a single female were transferred in November 1999 as the start of this operation. It was then discovered that the Mt Stokes population had decreased significantly and the decision was made not to transfer any more.

The population on Mt Stokes at this time was estimated to be something less than 20 birds (with an optimistic maximum of 27), of which only six were female. This decrease took the population back to 1996/97 levels. There were seven nesting attempts, all of which were much later than in previous years. Not only were there fewer nests (due to a loss of females over the winter) but success was poor with only two chicks fledging. The reasons for this poor breeding success are varied but include parasitism by long-tailed cuckoo and possibly predation. At the end of the season less than 20 birds could be found.

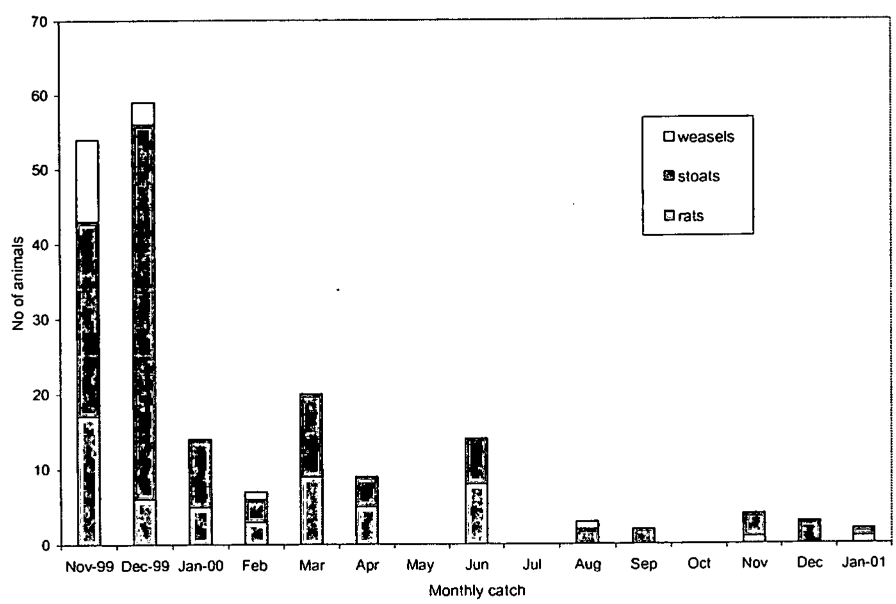
Stoat traps had been closed during this winter as regular checking could not be assured. They were re-opened in October and immediately rats as well as stoats were caught. Apart from the 22 rats caught in the Fenn traps, more were caught in possum traps set during pre-poison possum monitoring operations in November. High numbers of stoats were being caught early in the season, peaking at the end of the year and relatively few being caught by mid February 2000 when intensive servicing of the traps ceased.

Rats and stoats were both found to be less abundant to the north of the study area. A possible explanation for this is that during the winter of 1999, possum bait stations were loaded with pre-feed and were also laced with Feracol as there was a problem with rats. This regime did not extend to Mt McMahon where rat and stoat numbers were subsequently highest. It is possible that the Feracol directly reduced rat numbers and indirectly had some effect on stoats.

As the role of rats became more apparent this season, there was concern that trapping stoats may exacerbate the problem. In January 2000, a quick trial was done using Elliott traps set within the stoat trapping area of Mt Stokes, and also replicated in similar habitat near Mt Kiwi where stoats were not trapped. No rats were caught during 150 trap nights. One mouse was caught in the area where stoats were not controlled and 31 mice in the area where stoats were controlled.

Fenn traps remained set and were serviced once a month during the winter. Catch rates during this period are provided in Figure 1.

FIGURE 1. TRAPPING RESULTS FROM THE FENN LINE DURING WINTER OF 2000



2000/2001

In mid September 100 rat traps were set out on the slopes of Mt McMahon. No rats were caught on these lines over the summer, however, the Fenn line caught an additional three animals over this period (also provided in Figure 1). A comparison can be made between rats caught in Fenn traps during the winter of 2000 (Feb-Sept) when there were 8.1 animals per 10,000 trap nights, and during the summer (Oct 2000 to Jan 2001) when there were only 1.6 rats per 10,000 trap nights. This data is for uncorrected trap nights and as traps were checked less frequently during winter nights the contrast between seasons is likely to have been even greater.

Two staff were working on mohua exclusively from the beginning of November. This is usually the time that birds can first be detected. These staff searched intensively, and used play back equipment in the standard practice that has always produced results in previous years. There was no sign of mohua right through until 7 December when they were recalled.

4. Discussion

The effectiveness of stoat control in protecting mohua populations is well documented. The increase in mohua numbers on Mt Stokes under this regime was spectacular and regarded by the Mohua Recovery Group as the most successful management programme for the species. This can probably be attributed to the following factors.

1. Mountain top habitat, which could be protected by a contour 'fence' of stoat traps.
2. Intensive management of these traps, allowing protection of individual nests.
3. Operation of these traps in all years, not just after a heavy seeding.
4. The (initially,) essentially rat-free nature of the mohua habitat.

Against these factors the Mt Stokes population has been at risk from its small size and skewed sex ratio. Birds were at risk of being geographically isolated by the loss of their neighbours.

The turning point for this population appears to be related to the increase in rat numbers in the winter of 1999. An earlier mast year (in 1995) did not cause rats to colonise mohua habitat, and the expected influx of stoats which arrived in Jan 1996, was controlled sufficiently to allow for a big increase in bird numbers. Something was different in 1999, which allowed rats to increase.

We learnt about the colonisation of rats when the stoat traps were first activated after the winter. Coupled with this knowledge came the news from Fiordland that mohua had been observed roosting in holes and the realisation that they were therefore vulnerable to predation throughout the year and not just when breeding.

The decreased numbers present in spring 1999 led to a re-think on whether to complete the transfer to Nukuwaiata Island. After transferring one female and three males the decision was made to halt the operation.

The remaining population on Mt Stokes did not do well that breeding season, but nevertheless there were no great concerns for its viability. Because beech did not seed on Mt Stokes that summer, it was assumed the predator guild could be managed by the current level of effort.

Fenn trapping during the winter of 2000 revealed that some rats did persist, although their numbers were low, and had essentially disappeared by spring.

Without a more plausible suggestion I can only conclude that those few remaining rats, with no alternative seed source for food, were able to prey on hole-roosting mohua which, in addition to the usual winter attrition, was sufficient to extirpate the population.

Any discussion on the role of rats in the demise of mohua is not complete without reference to the unknown, yet possibly significant, extent that removal of stoats may have in enhancing rat numbers.

5. Conclusions

Conservation staff and contract workers have been successful in controlling stoats on Mt Stokes to the extent that mohua numbers increased ten-fold over a period of six years. The predatory impact of rats during the winter of 1999 was unexpected as:

- Mohua were not thought to be vulnerable to predation outside of the breeding season - their habit of roosting in holes was first observed later that year.
- Only one rat had ever been recorded before in this habitat and because of this were not regarded as the key predator in determining the survival of mohua.
- Stoats could be controlled effectively during a plague year (1995/96).

This background gives some explanation as to why the Fenn trap-line was not maintained during the winter of 1999. In hindsight if trapping had continued there would have been an early warning of the presence of rats and the ability of the stoat population to increase over the summer would have been reduced. It is debatable whether this trapping would have reduced rat numbers enough to ensure better survival of mohua. Either way, the impact on the mohua population could not be assessed until the birds become vocal in November.

It is more difficult to explain the poor breeding performance during the 1999/00 season and the subsequent demise of those birds during winter of 2000. It is likely that just a few rats continued to prey on breeding and roosting birds (although no evidence was found of this), and if this did not account for all birds then the continued presence of stoats and the usual causes of attrition, and chance probably accounted for the few survivors.

In many parts of the South Island there was a second masting of beech in autumn 2000 and a similar influx of rats was recorded along with a mohua decline reminiscent of the Mt Stokes experience. It may be that if mohua are to be conserved in the long-term it must be in locations where stoats can be controlled, rats are virtually absent, and where a contingency practice exists for intensive rat control over large areas, when necessary. This possibility is not certain anywhere on the mainland and it must therefore be necessary to consider translocation of some additional populations to island sanctuaries before the species can be considered secure.

No account of the work on Mt Stokes can be complete without acknowledging the hard work and dedication of all the people who were involved. This place is invariably cold, and wet, and always steep and we owe it to these people that the knowledge gained from their efforts will help ensure the survival of mohua.

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Assessment of an aftercare trial on a revegetation planting on Mangere Island with observations on planting style and herbicide site preparation

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Abstract

The herbicides Roundup™, Gardoprim® and Ronstar®, mulching with wool, and weeding are assessed on revegetation plantings on Mangere Island, Chatham Islands group. It is recommended that:

1. Plants are weeded once, and neither wool mulch, nor Ronstar® are applied.
2. The herbicides (Gardoprim® and Roundup™) continue to be used as a pre-planting ground preparation tool, provided that planting be delayed by at least 15 months after application of Gardoprim®, or two months after Roundup™ to allow for residual action to decrease.
3. A long-term trial is set up that monitors the long-term survival of plants planted by the newer technique of making a triangular hole versus firming into a large bowl of loosened soil.

1. Introduction

In December 1998 a trial was set up on Mangere Island in the Chathams group to look at the effect of different aftercare regimes for a revegetation programme. For the last decade the only aftercare that occurred was a thorough hand weeding of seedlings (mostly akeake (*Olearia traversii*)) about six months after they were planted. At this time any other problems were also dealt with, e.g., plants that needed straightening or firming in the ground. If the slope was too steep a flatter surface (of about 0.4m^2) was formed to aid moisture collection. All plants are tallied for survival during weeding.

The aftercare trial was located on grassy slopes in the Douglas Basin, on the south-facing slopes near the eastern end of the island.

2. Method

The herbicides Gardoprim® (Terbuthylazine) and/or Roundup® (Glyphosate) were used several months prior to planting to prepare the sites.

Akeake seedlings were grown in root trainers on Chatham Island. Shortly before transport to Mangere Island for planting, the soil was shaken from their roots[1] and they were packed with sphagnum and put into bags. This reduced the weight and volume of the plants to about one fifth of the original weight, and greatly reduced boating costs and effort needed to carry the plants to the planting sites.

Seedlings were planted when their average height was between 25 and 30cm. The height of each plant was measured (cm) and it was rated for vigour on a scale of 1 (almost dead) to 5 (excellent). Notes on each plant were taken, that recorded plant form, orientation, shoot die-back, foliage condition, and any signs of pest or nutritional problems. (The same characters were recorded when plants were re-measurement in February 2000.

Three plots were defined and treatments were replicated in these. Plots varied between treatment regime and age of planting.

PLOT 1

Plot 1 was treated prior to planting (in February 1998) with Roundup® and Gardoprim®. Bare-rooted akeake seedlings were planted in May 1998, and two treatments and a control were set up in 2000.

Treatments tested were:

1. Control: These plants received typical (status quo) treatment, i.e., thorough weeding approximately six months after planting.
2. Wool mulch: A 40-by-40cm square of lightly felted wool matting was pinned around each weeded seedling immediately following weeding for the plants in this treatment.
3. Ronstar®: Granular Ronstar® was sprinkled around the weeded plants (at a rate of about a dessert spoonful per plant).

In the six months between planting and weeding/trial establishment 20.7% of plants in Plot 1 had died (calculated as a percentage of the whole season's planting).

[1] All other species (e.g. Chatham Island mahoe, Chatham Island karamu, Chatham Island ribbonwood) are taken with unshaken roots as this disturbance has greatly reduced their early survival. Akeake appears to be relatively resilient in survival terms and suffers an acceptable reduction in growth rate as a result of this practice.

PLOT 2

Plot 2 was treated prior to planting (in April 1998) with only Roundup®. Bare-rooted akeake were planted in May 1998. One treatment was tested (wool mulch, as described above), and a control was also set up.

In the six months between planting and weeding/establishment of the trial, 13.9% of plants had died (calculated as a percentage of the whole season's planting).

PLOT 3

Plot 3 was planted in May 1997, a year earlier than the other plantings. It was not herbicide-treated prior to planting, but bare rooted akeake were used as in the other plantings. Two treatments were tested, which involved: (1) weeding the planted seedlings in both seasons (i.e., December 1997 and December 1998); and (2) weeding the plants in both seasons and also applying wool mulch after the second weeding. These were assessed against a third treatment, which was only weeded once at six months, and represented the background management undertaken.

The weeded and weed/wool-mulched treatments were alternated, but the treatment that was only weeded at six months was separated because of the unacceptable impact of randomising it with the more regularly weeded treatments.

In the months between planting and trial establishment, 5.1% of seedlings were dead or could not be relocated. This is a higher rate than in previous/subsequent seasons.

3. Results

PLOT 1

Forty-five of the 46 plants (97.8%) in the control had survived when re-measured; 43 of the 45 plants (95.6%) in the wool-mulched treatment had survived when re-measured; and 44 of 45 plants (97.8%) in the Ronstar® treatment had survived when re-measured. The average height and vigour of the plants in the various treatments in Plot 1 is provided in Table 1.

TABLE 1. AVERAGE HEIGHT AND VIGOUR OF PLANTS IN PLOT 1

Treatment	**Establishment (December1998)**		**Re-measurement (February 2000)**	
	average height (cm)	**vigour**	**average height (cm)**	**vigour**
Control	24.7 ± 3.0	3.2 ± 0.3	73.6 ± 3.0	3.7 ± 0.2
Wool	23.8 ± 3.4	3.0 ± 0.2	76.2 ± 6.3	3.8 ± 0.3
Ronstar	23.1 ± 2.8	3.0 ± 0.2	68.9 ± 6.4	3.5 ± 0.3

Errors denote 95% confidence interval.

The Ronstar® herbicide treatment and application of wool mulch had little influence on plant survival, height gain or plant vigour. The mean height and vigour of wool-mulched plants was a little greater than for the control and the Ronstar®-treated plants, but the scale of these differences was not significant. Wool-mulched and Ronstar®-treated plants tended to be more variable than the control plants. Survival was similar between treatments though slightly lower for wool-mulched plants, but again this was not significant. Notes observed on the plants indicate that wool-mulched plants appeared slightly bulkier and had more new growth. Plant vigour in the control and wool-mulched plants also improved significantly during the period (and probably represented more rapid recovery from the shock of bare-rooting, transport and planting).

PLOT 2

Forty-eight of the 49 plants (98.0%) in the control had survived when re-measured; and 46 of 51 plants (90.2%) that were wool-treated had survived when re-measured. The average height and vigour of the plants in the various treatments in Plot 2 is provided in Table 2.

TABLE 2. AVERAGE HEIGHT AND VIGOUR OF THE PLANTS IN PLOT 2.

Treatment	**Establishment (December1998)**		**Re-measurement (February 2000)**	
	average height (cm)	**vigour**	**average height (cm)**	**vigour**
Control	20.0 ± 2.9	2.7 ± 0.2	55.6 ± 5.6	3.9 ± 0.1
Wool	18.5 ± 2.9	2.7 ± 0.2	66.4 ± 5.3	4.0 ± 0.1

Errors denote 95% confidence interval.

In this plot, wool mulch conferred an average10cm height advantage over the control plants, however this was at the expense of a raised death rate, and was still not significant at the 95% confidence level. The average vigour of the wool-mulched plants was also slightly better, but was also not statistically significant. Notes observed on individual plants indicate that wool-mulched plants tended to be bulkier, and had a greater amount of new growth than control plants.

PLOT 3

Forty-nine of 50 plants (98.0%) in the control had survived when re-measured; all plants that had been weeded a second time had survived when re-measured; and 47 of 50 plants (94%) that were both weeded and wool-mulched had survived when re-measured. The average height and vigour of the plants in the various treatments in Plot 3 is provided in Table 3.

TABLE 3. AVERAGE HEIGHT AND VIGOUR OF THE PLANTS IN PLOT 3.

Treatment	**Establishment (December1998)**		**Re-measurement (February 2000)**	
	average height (cm)	**vigour**	**average height (cm)**	**vigour**
Control	39.0 ± 2.7	3.0 ±0.2	71.5 ± 4.8	3.7 ± 0.2
Second weed	42.0 ± 2.4	3.3 ± 0.2	78.0 ± 5.6	3.8 ± 0.2
Second weed & wool	40.0 ± 2.8	3.0 ± 0.2	82.6 ± 4.9	3.9 ± 0.2

Errors denote 95% confidence interval.

Plants that received a second annual weeding, combined with application of wool mulch grew significantly taller (by 11cm or 15%) than the control plants. Plant vigour rating was not significantly altered, though again the combined treatments had the highest mean value. Plants that were only weeded for a second time were slightly taller, but not significantly taller than the control plants. Notes on the individual plants suggested that the double weeded plants tend to be the bulkiest, with the greatest amount of new growth, but there were closely followed by the weeded/mulched plants.

Differences between the herbicide pre-treatments were also observed. The three plots are all in close proximity, and the plants used in Plots 1 and 2 are essentially from the same pool of 6000 seedlings planted in May 1998. Plot 1 seedlings planted onto a slope pre-sprayed with Gardoprim® and Roundup® in February were compared with those planted where Roundup® alone (Plot 2) was sprayed in April, i.e., like treatments were looked at control vs. control and wool vs. wool. The Gardoprim pre-treated plants were taller and more vigorous on average, but the differences were not significant at the 95% confidence level.

4. Conclusions

WOOL-MULCH

The application of wool mulch produced an insignificant increase in plant height and vigour, when applied to one-year old plants. In the case of two-year old plants, there was a small but significant increase when the wool mulch was applied at the time of the second weeding. The higher means for vigour probably can be attributed to plants developing a larger canopy with more healthily growing shoots in early summer. The effect may result from mulch protecting the soil from drying and therefore reducing growth inhibition in drought periods. Another possibility is the addition of nutrients as the mulch rotted.

Of concern is the small but important increase in death rate of plants receiving wool mulch. This was apparent in all three plots. Possible explanations include a grass problem and over-wet soil in winter.

The wool mulch inhibited grass establishment in the immediate vicinity of the plants, over most of the period of the trial. Possibly the moisture/nutrient aspects mentioned above also favoured development of tall grass at the edge of the mat. Without the support of a sward around the seedling, the grass edge then collapsed inwards over the top of the mat and small seedlings were rotted-off or smothered. Plants that had rotted were noted on several occasions. A second problem that was present in all treatments was the movement of plant stems with the wind, which crushed back the soil and formed a wet hole. The plants then thrashed around until roots or the stem was broken. This effect may be worse with moister soil, as occurs under the wool.

From an economic viewpoint, use of wool mulch requires a strong survival/height justification, which is not present. Plant purchase and the cost of three trips to Mangere Island (1. pre-planting spraying with clearing flax for planting, 2. planting seedlings and 3. weeding) results in plants in the ground at about $7.15 +GST, per plant. The purchase of the wool and pins with air transport to Chatham Island adds $1.65 +GST to each plant. When the additional boating[2] and labour[3] costs required to apply the wool mulch are taken into account, this figure increases significantly.

RONSTAR

The Ronstar treatment (Plot 1 only) seemed to slightly reduce plant performance (height and vigour), though the difference was not significant. Survival was the same as for the control. This treatment is therefore not recommended though of little additional cost.

WEEDING OVER SEVERAL YEARS

A second weeding produced a small increase in the mean height and vigour of plants over the 14 months of the trial. Again the greater performance of

[2] $350/hour probably for two 3-4 hour trips

[3] Five people at $9/hr for a six-day week.

plants weeded in two successive years was not significantly better than for plants weeded in year one only. Survival was very high for control and double weeded plants though fractionally better in the latter. A second weeding would require an additional cost of at least $1.50 +GST per plant that can not be justified by these early results.

PRE-PLANTING HERBICIDE USE

Use of Gardoprim® as a planting preparation was found to result in an unacceptably high early death rate of planted seedlings. This may be attributed to it having both knock down and residual activity. Gardoprim® resulted in at least a four-fold increase in seedling mortality, when seedlings were planted three months after spraying. Young plants were also observed to have a much greater initial shoot die-back, which was at least partially attributed to chemical damage.

This chemical is now used on the Chatham Islands by DOC, only to kill mats of *Poa chathamica* and then planting is delayed by 15 months to allow the residual capacity to subside. The slight height advantage in surviving plants probably resulted from a flush of nutrient availability from the decomposing grass - because it was sprayed earlier, the dead grass was more rotted than that in the Roundup® treated plots.

With Roundup® some shoot damage was also observed, and there was also a significant increase in mortality. There is a need to clear the grass for the planters so it is suggested the chemical is still used but a longer waiting period is applied.

PLANTING STYLE

Plant health was also affected by soil stability. The practice of planting bare-rooted trainer plants into a bowl of disturbed soil has been changed (since the set-up time of this trial) to planting the plant into the apex of a small triangular planting hole (so that two of three sides are firm soil). This has dramatically reduced the instance of plants collapsing sideways. When plants collapse, height growth ceases, and then resumes from new buds developed at soil level or from axillary buds. This reduces effective plant height and competitive ability (and hence survival) against grass in particular.

5. Recommendations

1. That the current aftercare practise is continued, i.e., plants are weeded once, and neither wool mulch, nor Ronstar® are applied.
2. Pre-planting treatment is continued (e.g., herbicides), in a manner so as to minimise adverse effects on newly planted seedlings. It is recommended to delay planting by at least 15 months after application of Gardoprim® and to allow at least two months between the use of Roundup® and planting.
3. A trial is set up to monitor the long-term survival of plants planted in the more recent fashion, i.e., the triangular hole versus firming into a large bowl of loosened soil.
4. Continue this trial and assess the survival, growth and vigour of the plants after five years.

A survey to determine whether a toxic fungal endophyte of tall fescue is present and being consumed by takahe on offshore islands

Ian Jamieson[1] and H. Sydney Easton[2] Return to Contents →

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Abstract

Tall fescue (*Schedonorus phoenix*) is a cultivated grass that is often infected with a fungal endophyte known to be toxic to livestock and other wildlife including birds. We determined whether tall fescue was present on two offshore islands (Maud and Tiritiri Matangi) where endangered takahe (*Porphyrio hochstetteri*) have been introduced and are known to suffer from high rates of egg infertility and poor hatching success. Despite extensive surveys, tall fescue was not observed on either island. Takahe on these islands fed almost exclusively on introduced grasses, particularly cocksfoot (*Dactylis glomerata*) and Yorkshire fog (*Holcus lanatus*), but none of these grasses are know to have toxic endophytes associated with them. We conclude that other factors must be responsible for the low reproductive success of takahe on islands. However, tall fescue is widespread throughout New Zealand and the possibility that it might become established on islands in the future means managers need to monitor presence.

1. Introduction

Although takahe (*Porphyrio hochstetteri*) that have been translocated to highly modified island refuges are generally healthy and have higher survival rates than those from the only remaining natural population in Fiordland, island pairs have higher egg failure and produce fewer chicks per egg than Fiordland pairs (Bunin *et al.* 1997; Jamieson & Ryan 2000). The majority of egg failures are due to high egg infertility (64%) with fertile eggs failing to hatch (24%) being the second most prominent cause of failure. This pattern of poor reproductive success has been evident since the initial founding birds first started breeding on islands in 1986 and, if anything, has become slightly worse in the last few years (1995 - 1997) (Jamieson & Ryan 1999).

Therefore there is no evidence that island birds are adapting or over coming this problem, at least not in the short term. Chemical residues left over from previous farm operations have been ruled out as a possible cause of the poor reproductive success (Jamieson & Ryan 1999), but naturally occurring toxins in introduced pasture grasses have not.

Toxins are often produced by fungal endophytes of many cultivated and wild grasses. The fungus obtains nutrients from the host plant, while the plant receives benefits that include protection from consumers, increased growth and survival, and increased competitive ability (Cheplick & Clay 1988). One grass species in the United States that is commonly infected with a fungal endophyte is tall fescue (*Schedonorus phoenix*). Infected tall fescue is known to decrease food intake and decrease weight gain in cattle (Hoveland *et al.* 1983) and decrease rates of development, growth and survival of insects (Cheplick & Clay 1988). In birds, infected fescue seeds have been shown to cause weight loss in several species of passerine, which also preferred non-infected seeds in choice trials (Madej & Clay 1991). Furthermore, Japanese quail (*Coturnix japonica*) fed a diet of 45% infected fescue showed a 10% reduction in male fertility (Zavos *et al.* 1993), although a second study on zebra finch (*Taeniopygia guttata*) showed no such effect (Conover & Messmer 1996). Some areas in the United States have had fields of tall fescue converted to native grasses to improve wildlife habitat, especially for birds (Washburn *et al.* 2000).

Tall fescue is a common component of pasture grasslands and grass-covered wasteland in New Zealand. This introduced grass species is often infected with an endophytic fungus *Neotyphodium coenophialum*, making the sward toxic to livestock (Christensen *et al.* 1998), with well-characterised ergopeptine alkaloids shown to be present in the foliage. Tall fescue infected with fungus is abundant in the takahe enclosures at Mt. Bruce (S. Easton, pers. obs.), where egg infertility rates have historically been extremely high (D. Eason, pers. comm.). Because tall fescue is now widespread in New Zealand, it is possible that it and its fungal endophyte also occur on offshore islands where it could be consumed by takahe. Although tall fescue was not listed as one of the main food species for island takahe in two different studies (Trewick 1996; Jamieson & Ryan 1999), it was not specifically searched for. Therefore the aim of our study was to survey Maud and Tiritiri Matangi Islands, sites where takahe are known to suffer from high rates of egg infertility (I. Jamieson, unpubl. data), to determine whether tall fescue is present, and if so, the extent to which takahe feed on infected plants relative to other available food species.

2. Methods

Surveys were carried out on Maud Island located in the Marlborough Sounds and on Tiritiri Matangi Island in the Hauraki Gulf, with the co-operation of

Department of Conservation staff. Surveys were conducted by traversing the islands using the system of well established tracks, which are often frequented by takahe, and by visiting all takahe breeding territories on the islands and looking for feeding sign (which takes the form of a pile of cut grass stems). On occasion, we were also able to observe takahe feeding directly. Samples of all food species were collected and brought back to AgResearch's Grassland Research Centre in Palmerston North, where they were identified by use of keys.

3. Results and Discussion

The surveys were carried out on Maud Island on the 23-24 November and on Tiritiri on 25-26 November, 1999. No tall fescue was found on either island. Seven territories were checked on Maud Island. Cocksfoot (*Dactylis glomerata*) and Yorkshire fog (*Holcus lanatus*) were the grass species that had been predominantly eaten. These were the dominant species in the areas where takahe were observed), however sweet vernal (*Anthoxanthum odoratum*), sow thistle (puha, *Sonchus oleraceus*) and phalaris (*Phalaris aquatica*) were also taken less frequently (Appendix 1). There was a small amount of fine fescue (*Festuca rubra*) in the pastures on Maud, but no tall fescue at all was seen.

Four territories were checked on Tiritiri, on three of which takahe were directly observed feeding. The prominent grasses that were eaten were cocksfoot and Yorkshire fog, and birds were also seen stripping bromus (prairie grass, *Bromus willdenowii*) of their seeds (Appendix 1). Seeds from Kentucky bluegrass (*Poa pratensis*) were also seen being eaten along with flower heads of cocksfoot and browntop (*Agrostis capillaris*). Perennial ryegrass (*Lolium perenne*) was seen near the tracks. This species is commonly infected with an endophyte related to that of tall fescue, and may also be toxic. However, there was no sign of takahe feeding on it. Again, no tall fescue was seen.

We conclude that tall fescue is either absent or extremely rare on Maud and Tiritiri Matangi Island. Therefore the toxic fungal endophyte that is known to be associated with tall fescue is unlikely to be the cause of the high rates of egg infertility in island takahe. Deficiencies in essential dietary nutrients have also being investigated, but preliminary results do not indicate any abnormal levels (Jamieson & Ryan 1999; I. Jamieson, unpublished data). However, the reproductive patterns we see in takahe are consistent with the hypothesis of environmentally-dependent inbreeding depression. Low egg fertility and low hatching and fledging success observed in island takahe may be signs of inbreeding depression resulting from transferring inbred birds adapted to the alpine habitat of Fiordland to the highly modified environment of these lowland offshore islands (see Jamieson & Ryan 2000).

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APPENDIX 1: GRASSES FOUND IN FEEDING SIGN OR DIRECTLY SEEN BEING EATEN BY TAKAHE ON MAUD AND TIRITIRI MATANGI ISLANDS.

Site	Location (grid ref.)	Feeding sign	Observed feeding
Maud Is.	Woodlands (28-29)	cocksfoot (x4)	-
		Yorkshire fog (x2)	-
		sweet vernal (x1)	
	Te Pakeka Pt. (65)	cocksfoot (x7)	-
		Yorkshire fog (x3)	-
	Southwood (68, 78, 83)	phalaris (x5)	-
		Yorkshire fog (x2)	-
		cocksfoot (x1)	-
	Radio Tower (72)	Yorkshire fog (x6)	-
		cocksfoot (x1)	-
		phalaris (x1)	-
	Top House (43)	cocksfoot (x4)	-
		Yorkshire fog (x4)	-
	Fort Road (15)	cocksfoot (x3)	-
		Yorkshire fog (x1)	-
		sow thistle (x1)	-
	Peninsula (91-92)	cocksfoot (x4)	-
		Yorkshire fog (x1)	-
Tiritiri Matangi Is.	Lighthouse (56)	cocksfoot (x3)	cocksfoot
		Yorkshire fog (x3)	Yorkshire fog
			bromus seed
			Kentucky bluegrass seed
	Ridge Track (38)	cocksfoot (x5)	-
		Yorkshire fog (x4)	-
	Landing (54)	-	cocksfoot flower head
		-	browntop
	Toilet Cable Track (36)	-	cocksfoot
		-	bromus seed
		-	browntop

An Inventory of Ecological Monitoring in Otago Conservancy: 1999

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In the reforming, Westernising years of the 1930's, a decree was issued that all Turkish citizens were to be counted. Everybody was to stay at home and usefully occupy themselves on census day. How the injunction was widely interpreted only became clear nine months later when previously unknown first name - Nufus, meaning population or census - enjoyed a popularity as widespread as it was short-lived.

Jeremy Seal. 1995. A Fez of the Heart. Picador

Abstract

An Inventory of Ecological Monitoring in Otago Conservancy was undertaken. Information was gathered through a staff questionnaire. 105 responses were received and analysed. Monitoring in Otago is concentrated on species and very little ecosystem health or trend monitoring is undertaken. Little review of monitoring has been completed or is expected to occur. A list of projects that are a priority for review is identified. Principles to be used in developing a Conservancy Monitoring Strategy are suggested.

1. Introduction

BACKGROUND

Monitoring is a technique to detect change over time. It involves repeat visits to a specific site or resource where data is recorded by standard or directly comparable methods. Monitoring can be used to detect the results of a management action or it may be used to understand natural variation in a species or ecosystem. Because of the diversity of resources managed by the Department of Conservation, and also the plethora of management actions the department undertakes, monitoring schemes come in many shapes and forms.

The Department has identified three types of monitoring, these are:

i) Outcome monitoring

ii) Result monitoring

iii) Surveillance monitoring.

These are defined, along with further definitions, principles and guidelines in: 'Measuring Conservation Management Projects' (Department of Conservation 1999).

Nationally the Department has prepared a Strategic Business Plan (known as "Restoring the Dawn Chorus"), which includes the following goal, relevant to guiding conservation management: to "*Conserve and restore the ecosystems in protected natural areas on land, through integrated management actions.*"

This goal is supported by the following objectives:

Objective 1.1.1: *Prevent, manage and control threats to maintain or improve the health of all natural areas that are important for natural heritage conservation.*

Objective 1.1.2: *Enhance population numbers and distributional ranges of species and subspecies threatened with extinction, where recovery action will be effective.*

Objective 1.1.3: *Protect and restore high value freshwater ecosystems.*

In addition, the recently published New Zealand Biodiversity Strategy (Anonymous 2000) identifies that most existing monitoring data is of limited use, in that it has gaps on important issues or over time, and cannot be aggregated or compared with results from other areas.

The Strategy also states that:

- *Monitoring agencies do not always have appropriate measures and methods to derive consistent information about key biodiversity issues and threats in their areas.*
- *Monitoring regimes are insufficiently linked to resource managers key biodiversity outcomes.*
- *Benefits from monitoring biodiversity are not often understood and statutory requirements to monitor the state of our biodiversity are not always complied with.*

In this context, Otago Conservancy is responsible for some 469,000 ha of land administered pursuant to several statutes and some 147 species that are considered to be threatened or at risk of extinction.

In order for the Conservancy to meet its obligations for improved non-financial reporting and to have confidence that the monitoring undertaken is effective and efficient, the Conservancy is preparing to develop a monitoring strategy. The first step in such a task is to understand what monitoring is already underway. To achieve this a questionnaire was used in 1999 to canvass Area and Conservancy staff on current monitoring programmes.

SCOPE

This inventory of monitoring broadly covers threatened species, pest management, and habitat monitoring for programmes included in Output Classes 4 and 5. It does not include monitoring for recreational programmes nor what is called operational auditing (Department of Conservation 1999) for weed or pest control operations.

2. Methods

Two methods were used to identify what monitoring the Conservancy undertakes.

QUESTIONNAIRE

DOC staff were asked to complete a short questionnaire for each monitoring project. A copy of the form with the response categories is in Appendix 1. The questions asked were:

1. *What is the name of the place where the monitoring takes place?*
2. *Who administers this place?*
3. *What is the focus of this monitoring?*
4. *What key questions do you want answered by this monitoring?*
5. *When was the monitoring established?*
6. *What is the ideal monitoring period?*
7. *When was the monitoring last carried out?*
8. *How long does it take to complete a session of monitoring?*
9. *For how much longer do you intend to run this monitoring?*
10. *Who undertakes this monitoring?*
11. *Where is the monitoring data stored?*
12. *What monitoring methods are used?*
13. *Is this monitoring meeting you needs?*
14. *Any other comments?*
15. *Who filled in this form?*

The questionnaire was designed to be simple and quick to complete. The intention was to record the type and scope of monitoring being undertaken rather than the detail of each programme. Quantitative information was sought in broad categories rather than being finely graded. The data from returned questionnaires were entered into a spreadsheet. For some of the questions, additional categories were defined to aid analysis. In the case of 'Administering Body', six categories were used. These were: DOC; Freehold; Pastoral Lease; Forestry Company; Local Authority; and LINZ. Any one monitoring programme could contain many administering bodies, as there were a mix of tenures in the returned questionnaires.

For analytical purposes, the question relating to the focus of the monitoring programme was split into two categories, to distinguish between those monitoring programmes which were habitat based and those that related to species. Some monitoring programmes included both and this was noted. For those monitoring programmes that were species based, the data were split into plant, mammal, insect, bird, lizard, fish or pest programme. Pest mammal species, such as goats and rodents, were not included in the mammal category but in the pest category only. Additionally the pest category included both plant and animal pest programmes. Responses relating to species programmes were further subdivided into 'Priority for Conservation Action Categories' defined by Molloy & Davis (1994). Categories used were A, B, C (priority species); I (species about which little information exists but which are considered threatened); M (important for Maori); and O (threatened in New Zealand but found elsewhere). Species included in the Ngai Tahu Claims Settlement Act 1998 as Taonga species, were also identified, as was a "no threat" category.

The question relating to Key Focus (Q.4) sought to establish why the monitoring was being undertaken. Replies were divided into the following three categories:

i) Species population trends. These programmes focused on indexing changes in numbers or population size of one or a few species (e.g., monitoring of trend in pingao, or rodents and mustelids in tracking tunnels).

ii) Species distribution trends. These programmes focused on spatial changes to one or a few species (e.g. programmes looking at invasion of islands by rodents or changes in distribution by fish species).

iii) Community condition trends. These programmes focused on several parameters of vegetation condition and normally involved many species (e.g. programmes monitoring changes in covenants or the impact of stock on protected areas).

Each of these categories included programmes that sought to: improve general knowledge of a species; or measure the impact of perceived competition and/or predation from other species; or measure the impact of a specific manipulation. Some monitoring programmes addressed more than one key question.

Replies relating to the actual activity of the monitoring, such as time since last completed (Q.7) and the amount of effort required (Q.8), were categorised into an appropriate scale for each question. For example, replies to the time since monitoring was established, were assigned to one of three categories (See Appendix 1).

NATIONAL INDIGENOUS VEGETATION SURVEY DATABASE (NIVS)

The NIVS Otago dataset directory (Burrows *et al.* 1991) was reviewed for this inventory. NIVS is a database of all indigenous vegetation survey data collected over the period 1920 to 1990 by the New Zealand Forest Service. Repeat measurements of these data sets using standard methodologies constitute monitoring.

3. Results

QUESTIONNAIRE

Area and Conservancy staff completed one hundred and five questionnaires. Key points from the returns are:

Location

Most monitoring programmes are undertaken in the Coastal Otago Area (n=44), followed by Central Otago (n= 35), Wakatipu (n= 14) and Wanaka (n= 12).

Most monitoring undertaken in the Conservancy occurs on public conservation land (n=72), followed by monitoring undertaken on freehold land (n=22). The majority of these latter programmes were for Conservation Covenant monitoring in Central. Monitoring programmes on land directly administered by Land Information New Zealand (LINZ) were next most numerous. Monitoring on Forestry Company lands occurs only in Coastal Otago Area and is only for indigenous fish.

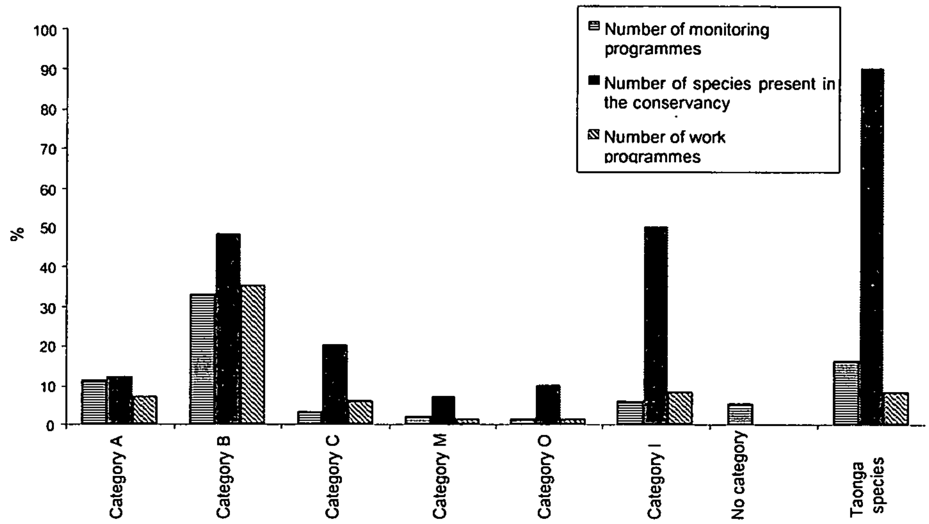
Monitoring on pastoral leases (n=6) is undertaken for birds (falcon) and threatened plants. The monitoring undertaken on land administered by LINZ was mainly for birds (braided river species) with one programme each for plant, fish and pests. Most monitoring on freehold land is for lizards. However, the establishment of Reserves at Emerald Stream will affect this result.

Species

By far the greatest number of monitoring programmes currently undertaken are species orientated (n=72). This result shows that the majority of the Conservancy monitoring effort within the scope of this inventory is directly related to OC5 programmes.

Most species monitoring programmes are for plants (n=22), followed by birds (n=19), then pest species, lizards, fish and mammals. The Conservancy does not have monitoring programmes for all Category A, B, C, M and, O species (Figure 1).

FIGURE 1: COMPARISON OF SPECIES MONITORING PROGRAMMES AND SPECIES WORK PROGRAMMES IN OTAGO CONSERVANCY.



In some categories, there are more monitoring programmes than numbers of species. This is because for some species there are two or more monitoring programmes in the Conservancy, (e.g., mohua, which has three monitoring programmes).

In Otago most Category I species are insects, however most of the monitoring programmes for Category I species are for fish. Most bird monitoring programmes are for either Category B or Taonga species. Most plant monitoring programmes are for Category B species, while most Category A programmes relate to lizards.

Monitoring programmes for species distribution trends are only undertaken in Coastal Otago Area (for goats and mohua) and Wanaka Area (pest presence on islands).

There are five monitoring programmes for species that have no category; these monitor seals and blue penguins. No attempt was made to quantify the number of species with no DOC priority category present in the Conservancy, as the number is probably in the thousands.

Effort

The length of time that monitoring programmes have been established was more or less evenly spread across the three categories of less than 12 months; 1-5 years ago and greater than five years.

Most monitoring programmes are re-measured annually. Monitoring established within the last five years has an annual re-measurement frequency, while programmes older than five years are more likely to be re-measured less frequently. Biannual, five-yearly and other re-measurements each contributed *c.*20 % of programmes. Most monitoring programmes were re-measured in the last 12 months.

Most monitoring takes less than five person days to complete (n=72), while a third take between five and 20 person days to complete. For four monitoring programmes, the respondees were unsure how long it took to complete a monitoring session. More plant monitoring programmes are completed in less than one day than any other programme types. Four bird programmes and one lizard programme take longer than 20 person days to complete.

Most managers had long-term aspirations for their monitoring programmes. Seventy-eight responses indicated an intention to run the programmes for greater than five years. Of those that it was intended to run for more than five years, most were going to be re-measured annually.

The current effort for the monitoring covered by the responses to the questionnaire is estimated to be at least 576 person days. Excluded from this are those programmes with non-even frequency of re-measurement.

One hundred of the responses showed that DOC undertakes the monitoring. Most of the data is stored in Area Offices; no questions were asked about the type of storage.

Techniques

Forty percent of responses included direct counts as a monitoring technique. A fifth included photography, 13 % included trapping. 60 monitoring programmes used fixed area sampling while 70 used permanent plots for monitoring. Most monitoring programmes that included direct counts were intended to detect species population trends. For community condition programmes photographs and direct counts were used. Cover class estimation, mapping, descriptive techniques and condition scores each contributed less than 5% of the total monitoring programmes. Trapping was the technique used most often for fish monitoring, followed by lizard and insect programmes. Plant monitoring programmes were most likely to use photographs. Mapping is only being used for plants and birds.

No technique stood out as particularly time consuming. For direct counts, effort to complete a monitoring programme was evenly spread from less than one person day to greater than 20 person days. Most programmes using photographs took less than one person-day to complete.

Managers needs

For 55 monitoring programmes, managers felt that their needs were being met. For 16 Category B species and five Category I species, the respondees were not sure if their needs were being met. Pingao (Coastal Otago Area) and Upper Shotover habitat condition (Wakatipu Area) are the two monitoring programmes not meeting manager needs. There were 30 species monitoring programmes for which Areas were not sure if the programme was meeting their needs, however there was an intention to run them for more than five years. There is 146 person-days per annum implied in this expectation.

NIVS

The Otago subset for the NIVS database contains 16 surveys within the Otago conservancy undertaken between 1970 and 1989. Surveys used a mixture of methods, including: quadrat diameter; quadrat sapling; quadrat seedling; RECCE inventory; point distance; ring transect; stereo photo; cruciform diameter; cruciform sapling; and cruciform seedling.

4. Discussion

General

Monitoring is an important technique to establish change over time. It is best undertaken by the application of established principles. These have been summarised in 'Measuring Conservation Management Projects' (Department of Conservation 1999). In developing a monitoring programme, often the hardest part of the process is identifying and defining the management need, and hence the question or questions to be answered by the monitoring. Once these are clearly established suitable monitoring methods, data collection and analytical techniques can generally be employed to address the questions.

Before embarking on a monitoring project questions such as, or similar to those below need to be answered (Allen 1999):

- Is any indication of density needed, and what question will that information answer?
- Is absolute density required or will an index of density suffice?
- Will a rough estimate answer the question or is an accurate estimate required?
- How much will it cost?
- Would that money be better spent on answering another question?

In addition the following points need to be addressed?

- What do you want to monitor and why?
- Has the question already been asked elsewhere?
- Are the results of monitoring likely to influence management direction?
- Is the issue controversial and likely to be heavily scrutinised?

Ideally the Conservancy should be undertaking monitoring to document changes in conservation resources and record the results of management (to an agreed, predetermined level). It needs to be recognised, however, that technical constraints can prevent effective monitoring of some species. Suitable techniques do not exist for many cryptic Central Otago species and invertebrates with specific emergence times. Future research may overcome these barriers. For others, a judgement may be required about where to spend resources (e.g. a distribution survey may be a higher priority, to determine potential monitoring sites).

At present Otago's monitoring emphasis is on species population trends. Monitoring programmes designed to detect a change in population status rely on prior knowledge of how much of a change in a population is significant. Our poor understanding of the ecology of many species means this knowledge may be lacking.

It is not always necessary to establish monitoring after every management action. This could be because we know with confidence what the result will be (e.g. when a fence is erected to exclude some browsers, we have enough experience to be confident that forest vegetation will regenerate).

Monitoring of habitat condition is not widely undertaken in Otago. The Otago subset of the NIVS data does provide a significant resource of baseline data and in some cases repeat surveys of both forest and grassland ecosystems. Grassland plots are not covered to a great degree in the responses to the questionnaire. This monitoring has been undertaken by the Department of Lands & Survey (and the data is now held by Knight Frank). Robust design has been integral to the NIVS dataset as well as the grassland plot data.

Wild animal impact surveys such as those in Mount Aspiring National Park or the MacLennan Block of the Catlins (Lovelock 1985) or bird distribution surveys (such as that conducted by Rhys Buckingham in the Greenstone/Caples) are generally not being repeated. One exception is the Greenstone vegetation plots, which are used to measure the impact of fallow deer.

Species

The Otago Conservancy does not undertake conservation management work on all Category A and B species present in Otago, and not all high priority species are monitored. For other species where the Conservancy does have a work programme it may still not be necessary to carry out a monitoring programme because the tasks such as survey or the development of a monitoring method take priority.

There appears to be little integration of species and ecosystem programmes within current monitoring. This may reflect the difficulties, without trying to understand the other links that occur in its habitat. Alternatively it may signal that until we can fill major gaps in basic ecology of some species, and determine the critical factors influencing them, monitoring is not practical. That there is more than one monitoring programme in the Conservancy for some species raises issues about unnecessary duplication or opportunities for replication. Any review of more than one monitoring programme at a single site should be undertaken at the same time to ensure that there is integration and robust design.

Effort

The current monitoring effort reported by the questionnaire represents at least 576 person-days per annum. This equates to a minimum current labour-only cost of $69,000 per annum (1999 dollars).

For many of the programmes, it is clear that managers intend to continue monitoring for extended periods without a review period and without being confident that the monitoring is meeting their needs.

Most of the monitoring established by Otago Conservancy is repeated annually. The questionnaires did not try to establish the reason for this frequency, but this may be because of the requirements of the business planning cycle, or the needs of the monitoring programme.

Techniques

The range of potential questions that could be asked of monitoring programmes is vast. Techniques, which may answer one question, may not be suitable for another, even though it may be closely related. Thus it is difficult to be prescriptive in identifying what monitoring methods should be used. People who are designing monitoring programmes have an obligation to ensure that they are clear about the objectives of the programme and the method chosen is the most appropriate.

Generally as monitoring designs become more specific for the effect(s) that they are measuring, the workload and resourcing required also increases. There usually is a threshold of effort and size of effect below which monitoring is not worth pursuing. Attempting to define these thresholds could take considerable effort but often by redefining the level of measurement or accepting more risk, an intuitive level of balance can be developed. Reviews of monitoring programmes are essential to check this and make refinements if appropriate.

Data storage and management are integral to running a successful monitoring programme. Much monitoring undertaken by DOC is intended to run over long time periods. Loss of data or changes to technology, which make it inaccessible, are impediments to successful monitoring. Development of robust data storage, retrieval and analytical systems in the Conservancy is essential. Development of GIS systems is a key to achieving this.

Techniques used for monitoring must be effective but they also need to be cost effective. An example of issues relating to design is the use of photographs in monitoring. The responses showed that 26% of Otago's monitoring programmes used photographs as part of, or the sole monitoring technique. Photographs are graphic, relatively cheap and quick. However a review for DOC (Allen 1994) showed that 64% of monitoring studies in the South Island tussock grasslands that used photographs, were not formally presented either to the institutions commissioning the studies or in a form accessible to, or able to be critically assessed by scientists or the public. Unfortunately a similar review of other monitoring techniques is not available. In the future, scrutiny of reporting of photographic monitoring by itself or in combination with other techniques is required to ensure that it is the most cost-effective method.

Managers needs

The response in the questionnaire under represented the amount of monitoring undertaken in the Conservancy by other organisations. For example there was no mention of the skifield monitoring that was recently reported on (Fahey & Wardle 1998). Nor was there any record of the plots that Alan Mark and co workers have established in Central Otago.

The decision whether or not to initiate monitoring needs to be take into account the following: what is being monitored; what is appropriate for the Conservancy's needs; and certainty that the programme has been designed in such a way that a viable result will be obtained. There is a clear expectation by many managers of maintaining existing monitoring programmes for extended periods. Programmes where managers are not sure that the programme is meeting their needs but which it is expected will run for more than another five years are a priority for review.

Clearly there are many species and ecosystems that are being monitored and that staff or external stakeholders have expectation should be monitored. To meet all these expectations with current resources, methods and biological knowledge is not currently practicable.

5. Conclusions

This inventory of ecological monitoring in Otago has shown that there is a great deal of diverse monitoring being undertaken by DOC staff and others in Otago. The amount of monitoring that is being undertaken in the Conservancy is under represented in this review. There is an emphasis on species population trends however a lack of understanding of species biology in some cases may limit the use of these results. Monitoring is not being carried out on all Category A and B species or on all high priority species. For some species, more than one monitoring programme exists.

Key gaps in the Conservancies current monitoring are:
- a representative range of ecosystems and ecosystem trend programmes especially in the tussock grasslands;
- a lack of integration of species and ecosystem monitoring; and
- lack a of clear outcome for some programmes indicating a need for review.

6. Recommendations

It is recommended that OMT:
1) Receive this report on Ecological Monitoring in Otago Conservancy;
2) Implement a review of:
   a) those monitoring programmes which are identified as being expected to run for greater than five years but for which managers are unsure whether the programmes will meet their needs; and
   b) multiple monitoring programmes for the same species to identify efficiency gains by co-ordination of Area efforts;
3) Encourage Area Managers to obtain a more complete understanding of ecological monitoring undertaken by other agencies and its relevance to their management;
4) Develop standards for data storage and retrieval including the use of GIS; and
5) Proceed to develop a monitoring Strategy for Otago Conservancy that emphasises a robust process for determining monitoring needs and sound programme design.

Acknowledgements

Marcus Simons greatly improved versions of this report.

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APPENDIX 1: MONITORING FORM CIRCULATED TO DOC STAFF.

Area ______________________

1.	What was the name of the place where monitoring takes place?	
2.	Who administers this place?	☐ DOC ☐ Other (State ____________.)
3.	What is the focus of this monitoring?	☐ Species specific ☐ Habitat or ecosystem condition ☐ Other (Specify ____________.)
4.	What key questions do you want answered by this monitoring?	If you need more space use the back
5.	When was this monitoring established?	☐ Within the last 12 months ☐ 1-5 years ago ☐ More than 5 years ago
6.	What is the ideal monitoring period?	☐ Monthly ☐ Biennial ☐ Biannual ☐ Every 5 years ☐ Yearly ☐ Other (State ____________.)
7.	When was monitoring last carried out?	☐ Within the last year? ☐ 1-5 years ago? ☐ More than 5 years ago?
8.	How long does it take to complete a session of monitoring?	☐ < 1 person day ☐ more than 2 person days ☐ 1 person day (state ____________.) ☐ 2 person day
9.	For how much longer do you intend to run this monitoring?	☐ 1 year ☐ more than 5 years ☐ 1-5 years
10.	Who undertakes the monitoring?	☐ DOC ☐ Landcare Research ☐ University ☐ Other (____________.) ☐ Knight Frank
11.	Where is the monitoring data stored?	☐ Area Office ☐ Landcare Research ☐ Conservancy office ☐ Other (____________.) ☐ Knight Frank ☐ Don't know
12.	What monitoring methods are used?	(e.g. height frequency, 5 minute bird count, etc.)
13.	Is this monitoring meeting your needs?	☐ Yes ☐ No ☐ Not sure yet
14.	Any other comments?	
15.	Who filled in this form?	

The impact of cattle on beech (*Nothofagus* spp.) forest edge regeneration in the Dart Valley, Mt Aspiring National Park, Otago

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Abstract

The long-term effect of cattle grazing on beech forest margin is assessed through the use of variable (RECCE) plots and fixed plots. These were tested by using a two-tailed independent sample t-test; by two sample Kolmogorov-Smirnov Goodness of Fit tests; and ground cover classes were compared between sites using a Mann-Whitney U test.

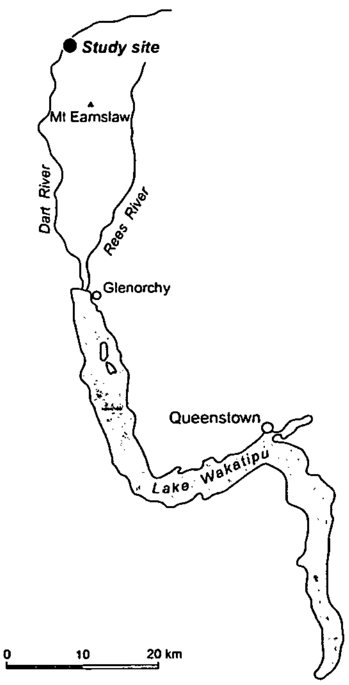
Grazed and ungrazed sites showed significant differences in relation to stem densities, ground cover class proportions, and species composition. In grazed sites, the diversity of plants within the forest margin is significantly less, and rock, litter and bare ground is more abundant than in ungrazed sites, and canopy recruitment is not occurring. The removal of cattle impacts is essential to prevent retreat of the forest margin at Cattle Flat.

1. Introduction

Cattle (*Bos taurus*) are grazed on Cattle Flat in the Dart Valley (Figure 1) during winter. The grazing is permitted as part of undertakings made to lessees when Mount Aspiring National Park was established in 1964 and is now authorised through concessions issued by the Department of Conservation pursuant to the National Parks Act 1980.

There has been anecdotal comment on the impact of cattle on the beech (*Nothofagus* spp.) forest and whether such grazing should be permitted. In particular, comment has been made that regeneration of beech along the margins of the forest is absent or very depleted when compared with similar areas elsewhere in the Park.

FIGURE 1. MIDDLE DART VALLEY SHOWING THE LOCATION OF THE FOUR GRASS FLATS AND THE 22 PLOTS WHERE VEGETATION WAS SAMPLED.



When discussing the impact of introduced animals on beech forest, Wardle (1984) noted that domestic cattle modify beech forest adjacent to pasture where not excluded by fencing. He wrote "*the damage is particularly severe in small stands surrounded by grassland and on terrace forest bordering grassland. Cattle are less selective browsers than red deer, and this, combined with breaking and trampling, often leads to rapid destruction of understorey shrubs, tree seedlings and saplings, and their replacement by grasses, sedges and other herbs.*"

Cattle have been grazed in the Dart Valley for about 100 years. Traditionally all the flats (i.e., Cattle, Quinns, Daleys and Dredge Flats) in the valley have been grazed but since the late 1980's restrictions have been placed on some on the grazing. In particular, Quinns and Daleys Flats have been excluded from the licence and Dredge Flat has also not been grazed. The licence allows for up to 200 head of cattle to be grazed on Cattle Flat during the winter. In practice only about half of this number are pastured on the flats.

We compared species composition, ground cover and stem density at Cattle Flat and the lower flats to assess the impacts of cattle on the beech forest margins. We chose to use a treatment and non-treatment sample approach rather than monitoring change over time in recognition that any effects were likely to have been well established after 100 years of grazing.

The lower flats were chosen as non-treatment sites as they represented the closest comparable non-grazed sites. We recognised that cattle crossed them on their way to Cattle flat but the effects are only for 2-4 days per year as opposed to 3-4 months at Cattle Flat.

In setting up this work a number of assumptions were made concerning the study sites. In particular, we assumed that the collective variables which determine forest structure, and the impacts of wild animals such as deer (*Cervus elaphus*), possum (*Trichosurus vulpecula*) and hares (*Lepus europaeus*), were the same at both sites.

2. Study sites and methods

STUDY SITES

Cattle Flat is the largest of the four areas sampled, being 4km long and approximately 155ha in extent. It has a northerly aspect and is approximately 640m above sea level. It is a dissected post-glacial fan terrace with a toe of more recent alluvium. Cattle Flat has the longest snow lie of the four study sites (R. Kennett pers. comm.).

The lower flats are comprised of river alluvium. Quinns (10ha), Daleys (30ha) and Dredge (85ha) range in elevation from 460-500 metres above sea level. Only a relatively small area of Dredge Flat at the northern end was sampled. Quinns and Daleys Flats have a north-westerly aspect and Dredge Flat an easterly aspect. Dredge Flat is on the true right of the Dart River while the other flats are on the true left. This split sampling, while not ideal, was necessary to obtain a similar number of comparable plots as that obtained at the grazed (treatment) site.

The vegetation covering the four sites is similar with the pasture areas being dominated by a mix of exotic grasses particularly brown top (*Anthoxanthum odoratum*), with indigenous herbs (e.g., *Mazus radicans, Herpolirion novae-zelandiae* and *Pratia angulata*) and sub-shrubs (e.g., *Leucopogon fraseri* and *Gaultheria depressa*) scattered throughout as minor components. Shrub weeds (e.g., gorse) are absent from all sites. Mountain beech (*Nothofagus solandri* var. *cliffortioides)* forest bounds all four flats. Red beech (*Nothofagus fusca*) and silver beech (*Nothofagus menziesii*) are present as occasional components of the canopy. The beech/pasture margin at Cattle Flat is abrupt while the margin on the lower flats consists of a narrow band of regenerating beech.

METHODS

Forest structure data and ground cover data were collected using the RECCE inventory method (Allen 1992). Stem size data were collected by establishing a 10×20m plot, and measuring the diameter of all stems at breast height (dbh). For saplings under 2cm dbh, the number present were counted. These plots were fixed with one boundary along the drip line of the canopy onto the grassland, with the plot extending into the forest. Plots were subjectively located to maximise spatial spread along representative forest edge at both sites. Steep sites inaccessible to stock were avoided. Twelve plots were measured at Cattle Flat and 10 plots at the lower flats.
Each plot was photographed.

Variable plot (RECCE) data were analysed by comparison of number of species per site. This was tested by using a two-tailed independent sample t-test.

Fixed plot samples were analysed by two sample Kolmogorov-Smirnov Goodness of Fit tests.

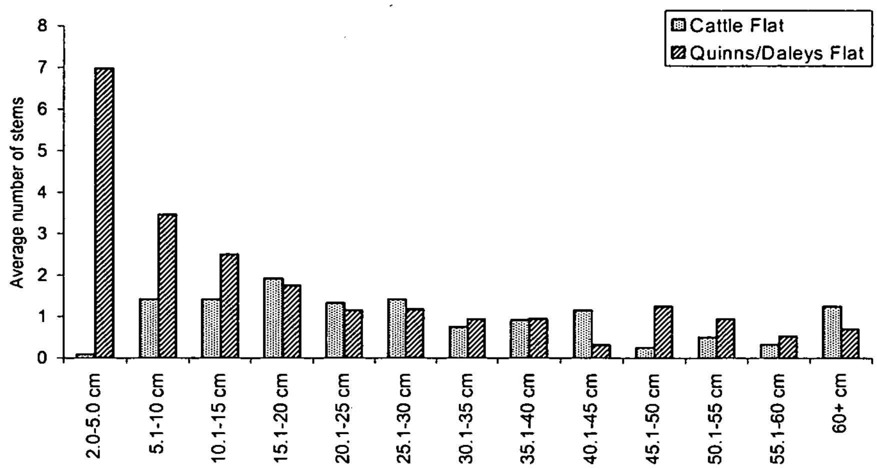
Ground cover classes were compared between sites using a Mann-Whitney U test.

3. Results

STEMS PER PLOT

Comparison of the treatment and non-treatment sites required that they were similar. Figure 2 shows average diameter values for stems greater than 2.0cm. This graph shows that above 15.0cm dbh, stem size class distribution is

FIGURE 2. COMPARISON OF AVERAGE NUMBER OF STEMS GREATER THAN 2CM



similar (Kolmogorov-Smirnov two tailed statistic = 0.08 P=0.98). Figure 3, which includes diameter classes below 2.0cm, shows that there is no recruitment to the forest at Cattle Flat, while at the lower flats there is substantial recruitment. Note the different scale for the y-axis between Figure 2 and 3.

FIGURE 3: COMPARISON OF AVERAGE NUMBER OF STEMS PER PLOT.

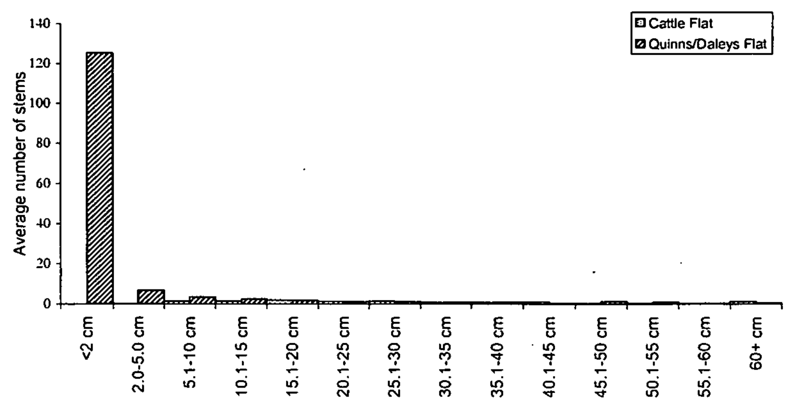
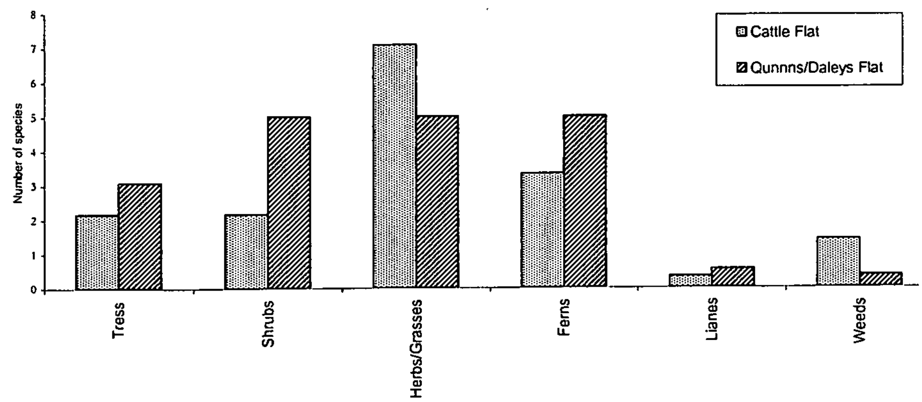


Figure 4 shows the average number of species per plot for six broad plant groupings. The weed group is a subset of herbs/grasses. At Cattle Flat, trees, shrubs and ferns were less numerous and herbs, grasses and weeds more common than at the non-treatment sites. The differences in number of species between sites for trees, shrubs, and weeds were significant (trees t=2.597, $p<0.05$; shrubs t=3.760, $p<0.05$; weeds t=-2.094, $p<0.05$).

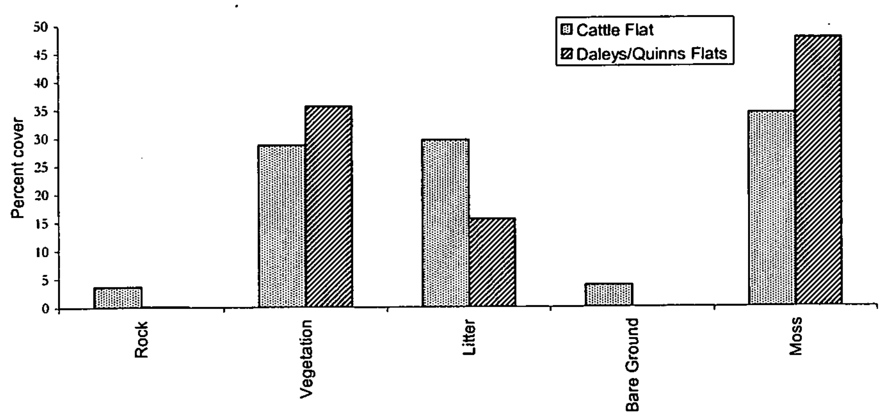
FIGURE 4: COMPARISON OF AVERAGE NUMBER OF SPECIES FOR SIX PLANT GROUPS.



GROUND COVER

In both treatment and non-treatment sites, moss was the dominant ground cover (Figure 5). There is evidence that moss was less common at the lower flats than at Cattle Flat although this was not significant. The second most common ground cover was vegetation. At the lower flats, bare ground was absent and rock almost absent (mean contribution 0.11%). Bare ground and rock were present at Cattle Flat and this difference was significant.($p=0.015$ for rock; $p=0.023$ for bare ground). Litter was more common at Cattle Flat although this was not significant.

FIGURE 5: COMPARISON OF COVER CLASS CONTRIBUTION FOR FIVE CATEGORIES OF GROUND COVER.



4. Discussion

The forest at both treatment and non-treatment sites was broadly similar. Mountain beech is the dominant canopy species at both sites, with silver and red beech contributing to a lesser and varying extent. Tree density and size class distribution, as determined from analysis of stems per plot, was similar for stems above 15.0cm dbh.

We think use of the forest by cattle is predominantly for shelter during adverse weather, and it is during such events that their impacts are concentrated on the immediate margin. While the adjacent grasslands principally meet their grazing requirements, browsing of forest understorey species at such times is an inevitable consequence.

Analysis of ground cover showed that significantly more rock and bare ground, as a percentage of ground cover, is present at Cattle Flat than at the lower flats. This is attributed to the effects of cattle trampling and other cattle disturbance at this site. This is also consistent with evidence of less vegetation and moss cover, and more litter at Cattle Flat than at the lower flats.

The complete absence of stems <2.0cm dbh at Cattle Flat (Figures 3, 8 & 9) is in dramatic contrast to their relative abundance at the lower flats (Figures 10-13). Large differences in stem density also exist between the sites for the 2.1-5.0cm size class. Smaller differences continue for size classes between 5.0-15.0cm dbh. Calculations of stem diameter/age relationship for mountain beech in the 'Fiord' district (Wardle 1984) indicate that a dbh of 15.0cm is reached at about age 100 years. This correlates well with the length of time cattle have been grazed in the Dart Valley.

We suggest that these differences are correlated to the intensity and time that cattle grazing has occurred in the Dart Valley. Although we lack a clear understanding of the cattle management regime over the entire grazing period, we know cattle grazing essentially ceased ten years ago at the lower flats. This has enabled a pulse of regeneration to occur at the lower flats as represented by the large number of stems <2.0cm dbh. The greater number of stems in size classes 2.0-15.0cm dbh at the lower flats compared to Cattle Flat cannot be attributed to ten years of non-grazing. Instead, the data suggests that prior to 1989, cattle grazing had less impact on forest regeneration on the lower flats compared with Cattle Flat. This may have been the result of a reduced stocking intensity.

The lack of recruitment of canopy species at Cattle Flat clearly has significant implications for the maintenance of the current forest margin. As large old trees fall from or near the forest margin, the space they previously occupied is taken up by pasture grasses, weeds and ferns, rather than juvenile canopy species. In effect, the pasture edge moves into the forest (Figure 6).

The forest margin at Cattle Flat has an irregular outline and includes lobes of forest connected by narrow "necks" to the main forest block. We observed loss of trees from these "necks", and speculate that their subsequent non-replacement is leading to fragmentation of the margin through isolation of small forest patches previously connected (Figure 7). While this process is slow and incremental, the increasing mean age of trees on the forest margin, suggest the rate of tree loss will accelerate in the future. A natural catastrophic event (e.g., landslide, windthrow) could amplify this process.

The impact of cattle at Cattle Flat has resulted in reduced species diversity of most plant groups in comparison with the diversity present at the lower flats. As predicted by Wardle (1984) and stated in our introduction, tree and shrub species showed the greatest decline and were replaced by a mixture of native and exotic herbs and grasses.

Weeds, which are subset of the category labelled herbs/grasses in Figure 4, were significantly more abundant at Cattle Flat than the lower flats. We believe this is a consequence of the predominance of suitable establishment sites (disturbed or bare ground and high light levels) present at the site and is attributable to cattle grazing and trampling.

The impact of soil compaction from cattle trampling may also be important. Trimble and Mendel (1995) in their critical review of cattle impacts on geomorphology observed that cattle directly reshape the earth, compact the soil, cause increased runoff, and change soil susceptibility to both water and wind erosion. They report that soil fauna have more difficulty surviving in the impacted soils resulting from heavy grazing.

5. Conclusions

Grazed and ungrazed sites showed significant differences in relation to stem densities, ground cover class proportions, and species composition.

The data gathered supports anecdotal comment that regeneration of beech along the forest margin at Cattle Flat is absent or very depleted, compared with flats lower in the Dart Valley.

Native plant diversity within the forest margin is significantly reduced at Cattle flat in comparison with the lower flats.

Rock, litter and bare ground is more abundant within the forest margin at Cattle Flat in comparison with the lower flats.

IMPLICATIONS FOR MANAGEMENT OF CATTLE FLAT

The beech forest edge at Cattle Flat is not being replaced as constituent trees die. While this process is slow and incremental, the increasing mean age of trees on the forest margin suggests the rate of tree loss will accelerate in the future. The removal of cattle impacts is essential to prevent retreat of the forest margin at Cattle Flat.

The cessation of cattle impacts can be expected to result in spectacular beech regeneration and improved shrub and tree species diversity.

6. Recommendation

If forest regeneration is required and further deterioration of forest edge values at Cattle Flat are to be avoided, then cattle grazing should cease at the earliest opportunity.

FIGURE 6: CATTLE FLAT BEECH FOREST MARGIN ON MODERATELY STEEP SLOPES SHOWING LOSS OF EDGE TREES, DECEMBER '1998.

FIGURE 7: FRAGMENTATION OF FOREST EDGE CATTLE FLAT, DECEMBER 1998.

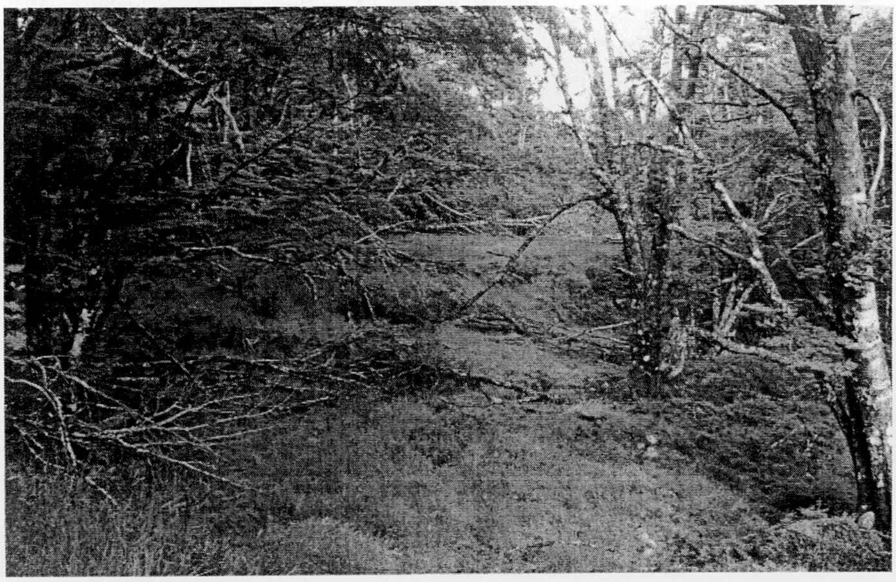


FIGURE 8: CATTLE FLAT FOREST MARGIN PLOT WITH HIGH DENSITY OF BEECH STEMS, DECEMBER 1998.

FIGURE 9: CATTLE FLAT FOREST MARGIN PLOT DOMINATED BY FEWER, OLDER BEECH TREES, DECEMBER 1998.

FIGURE 10: BEECH AND *COPROSMA* REGENERATION ALONG FOREST MARGIN AT QUINNS FLAT, DECEMBER 1998.

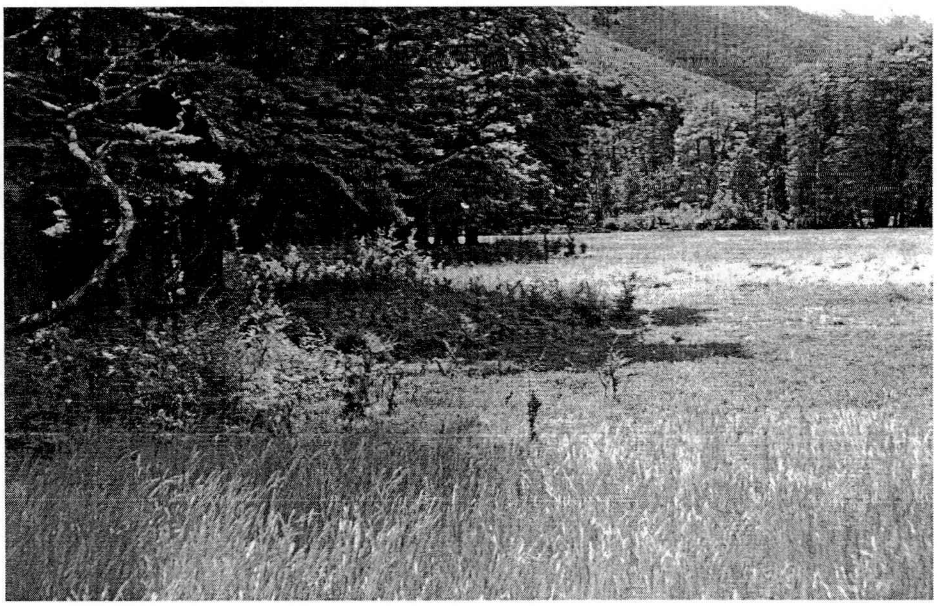


FIGURE 11: BEECH REGENERATION ALONG FOREST MARGIN AT QUINNS FLAT, DECEMBER 1998.

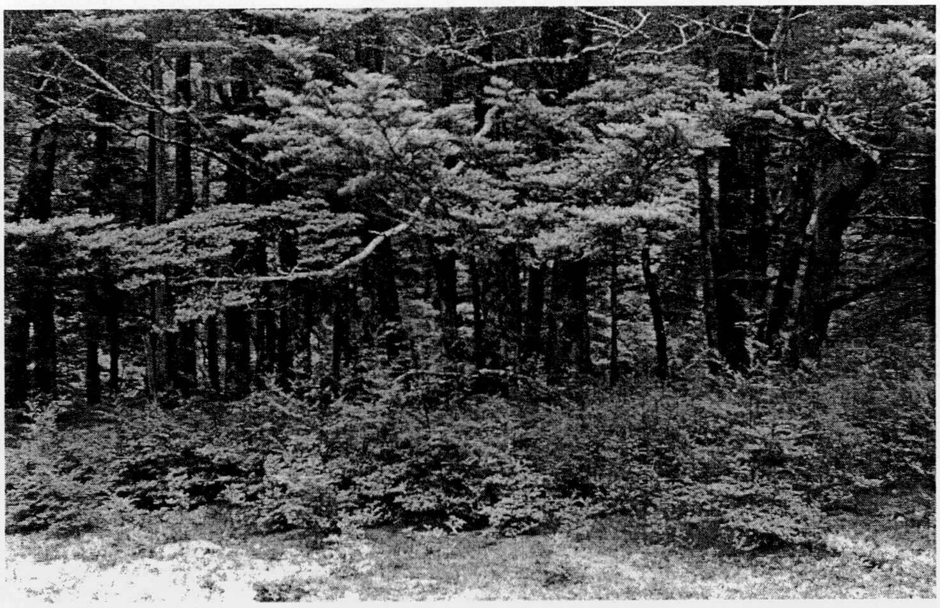


FIGURE 12: BEECH REGENERATION ALONG FOREST MARGIN AT QUINNS FLAT, DECEMBER 1998.

FIGURE 13: BEECH REGENERATION ALONG FOREST MARGIN AT DALEYS FLAT, DECEMBER 1998.

Acknowledgements

We thank Henrik Moller and Mandy Tocher for statistical advice, Geoff Rogers for advice on experimental design, and Richard Kennett for logistical support and history of grazing.

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Possum and ship rat control using encapsulated potassium cyanide (Feratox®) within three rodenticide-laced pastes via a biodegradable bait station

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Abstract

The results of three investigations into control of possums and ship rats in Northland, New Zealand, using cholecalciferol, diphacinone or warfarin in combination with encapsulated potassium cyanide (Feratox®) are presented. These suggest that possum control similar to conventional aerial 1080 pollard or ground-based 1080/Talon® application is possible with the added bonus of rat control. However, anticoagulant rodenticides performed better than cholecalciferol, which did not reach rat control targets and may have contributed to possum control targets not being reached during the same operation. Poisons were presented via raised, visually uninteresting biodegradable bait stations that removed the labour of pre-feeding, reduced visual impact and placed the station out of reach of many terrestrial non-target species, and target animals appeared to have no problem finding them.

At an approximate cost of $15.00/ha, this bait presentation method compares very favourably with most other methods commonly used for possum control, and can potentially provide the added benefit of effective rat control, good continuity of effect on possum densities and minimal establishment and maintenance costs.

7. Introduction

North Island kokako (*Callaeas cinerea wilsoni*) require intensive nest protection from predation by possums (*Trichosurus vulpecula*) and ship rats (*Rattus rattus*). As a means of developing nest protection techniques, a simple trial was undertaken in February and March of 1998 to assess the effects of combining the anti-coagulant diphacinone with Feratox® within 12ha plots. Small amounts of bait were delivered weekly via Romark® stations on a 70×70m grid. The approach appeared to reduce pest animal indices but highlighted the slow response to this "drip feed" approach when using anti-coagulants, which require multiple consecutive feeds to be effective (DOC unpublished report). Since then, the combination of diphacinone-laced peanut paste and Feratox® within waxed cardboard tubes has been successfully used in Northland Conservancy for the protection of nesting kokako (Gardner 1999).

A more extensive trial was undertaken in August 1998, within 90ha of native forest surrounded by pines. A non-treatment "control" block was monitored concurrently. Tubular waxed cardboard stations containing *c.*400g of 0.01%w/w diphacinone in peanut paste and eight, evenly spaced Feratox® capsules, were pinned to the ground with wooden dowels on a 70×50-metre grid. Monitoring was via 30 baited rat-tracking tunnels and 30 raised victor softcatch leghold traps placed at 50-metre spacing along three compass line transects within both blocks.

This second trial was partly compromised, as its timing coincided with pine pollen season, which appeared to cause a migration of possums from, and then back to the trial area. Despite this, the trial successfully reduced ship rat densities by approximately 95%, to a residual tracking rate (RTR) of 3.3%, and possums by 78% to a residual trap catch (RTC) of 7%. The result of this trial was sufficiently encouraging to warrant repeating in an area where the local effects of pines could be avoided.

This paper reports on trials carried out in September and October 1999, 2000 and 2001 with the objective of reducing target pest indices to below 3%.

8. Materials and Methods

STUDY SITES

Trials were undertaken in Pukenui Conservation Forest, approximately 4km northwest of Whangarei. The area is part of a larger forest tract (*c.*1,100ha), which contains 32 distinct ecological units, making it the second most diverse forest in the Whangarei Ecological District (Manning 2001).

The treatment area comprises 100ha of forest dominated by taraire (*Beilschmiedia tarairi)* and towai (*Weinmannia silvicola)* with occasional emergent podocarps. A small section (*c.*5-10 ha) is dominated by kanuka (*Kunzea ericoides*). Topography varies considerably from alluvial flats to moderately steep hillslope, but is generally moderately rolling. Altitude varies from 120 to 254 metres above sea level.

The non-treatment area is within the same tract of forest, 1km to the northwest. Forest types are similar but without the alluvial flats, and kauri (*Agathis australis)* is more common.

TREATMENT METHOD

Application methods remained the same for each of the three trials. The tubular waxed cardboard stations were reduced in capacity from 400 grams to 350 grams, but otherwise the same as those used in the 1998 trial. Spacing and station siting were changed. A more "practical" grid line spacing of 100m was chosen along which stations were placed at 50-metre intervals, giving an approximate 100×50-metre grid. Stations were laid out from a central base line using a compass and 25 metre-long string. A total of 100ha were treated in this way at an application rate of 700 grams per hectare. Stations were also elevated approximately 1.5m off the ground to avoid non-target animals, especially feral pigs which had previously eaten peanut paste bait during kokako nest protection. Each station was nailed to a suitable sloping or forked tree using two 75mm flathead nails.

In the 1999 trial, stations contained 0.01% diphacinone in a peanut paste, with eight cyanide pellets.

In 2000, several changes were made. Synergised warfarin (0.025%) was used as the rodenticide (in place of diphacinone). The number of cyanide pellets was reduced from eight to six in each station (in response to lower possum densities within both the treatment and the non-treatment block), and non-toxic prefeed pellets were inadvertently omitted from the peanut paste.

In the 2001 trial 0.1% cholecalciferol in a rice-based paste with eight cyanide pellets was used.

Feral Control Ltd currently produces these pastes under a provisional registration.

MONITORING METHODS

Monitoring was run concurrently at the treatment and non-treatment "control" blocks using the same devices, spacing and layout.

Rat indexing was carried out over one night using three lines each of 13 tunnels which, for the 1999 and 2000 trials, were baited with orange-lured kibbled maize and flour in order to be attractive to potentially bait-shy rats. This was because the paste matrix used during these trials was peanut butter based. The 2001 trial used a rice-based matrix, and so peanut butter was used as the lure for rodent tunnels during that trial.

The tunnels were placed at 50-metre intervals, parallel with, and mid way between the poison grid-lines. They were therefore potentially biased towards detecting rats that may have survived in pockets between the poison lines, but covered the full range of topographic and forest types. The tunnels were put in place at least 12 days before the first index was run and remained in place for the following trials. The pre-poison index was run in the week before the operation and the post index approximately two weeks after the operation.

Possum indexing was carried out using 40 Victor soft-catch leghold traps, raised approximately 700mm off the ground on "Scott boards". Traps were set 20m apart for three consecutive nights and were baited with orange-lured flour. The trap line generally ran perpendicular to the rat and poison lines to minimise the impact of catching non-target rats near the rat index lines. All traps were set "coarsely" for the same reason.

Captured possums were released following advice from Landcare Research that "catchability" of possums is not affected, provided the post index is carried out at least two weeks after the pre index (M.D. Thomas pers. comm.).

The limited area and financial resources of the trial restricted the number of monitoring devices used. However, monitoring methods and sample sizes were more robust than for the previous trials. While neither the possum, nor rat-indexing methods were entirely according to national protocol, most changes were likely to affect only the statistical robustness of the results, and so could be compared with other monitored Northland sites.

Forty stations on a sample of poison lines were marked with dazzle to allow bait take to be estimated from up to 40 stations. Mean bait take was assessed one, two and three weeks after placement, and stations were then checked periodically until all bait had been consumed or take had ceased.

9. Results

RESIDUAL TRAPPING/TRACKING RATES

Data were analysed using standard protocol. The percent change for the treatment index was adjusted to take into account the trend evident in the non-treatment index. Results are shown in Table 1.

Diphacinone

The 3% target was achieved for possums but not quite reached for rats. Twelve rats were caught as a by-catch of the possum index in the treatment area and 18 rats were caught in the non-treatment area. No rats were caught as a by-catch of the possum index in the treatment area, whereas 17 were caught in the non-treatment area.

Warfarin

The 3% target was achieved for rats but not achieved for possums. Results for the 2000 warfarin trial followed a similar pattern for rats as the 1999 diphacinone trial. (See Table 1.) Twenty-two rats were caught as a by-catch of possum indexing in the treatment area and twenty-one were rats caught in the non-treatment area. No rats were caught as a by-catch of possum indexing in the treatment area and five were caught in the non-treatment area.

TABLE 1. TARGET PEST REDUCTION

Trial	Pest	Site	Pre R.T.C./R.T.R.	Std. Err.	Post R.T.C./R.T.R.	Std. Err.	% Change
	Ship rat	Treatment	54.00%	6.40	5.10%	5.00	-92.00%
1999		Non-treatment	76.30%	7.70	94.60%	4.90	+19.00%
Diphacinone	Possum	Treatment	28.10%	3.60	0.80%	0.75	-98.00%
		Non-treatment	29.10%	5.45	37.60%	2.25	+30.00%
	Ship rat	Treatment	46.90%	7.31	0.00%	0.00	-100.00%
2000		Non-treatment	53.00%	15.12	73.60%	7.68	+39.00%
Warfarin	Possum	Treatment	17.00%	6.10	14.25%	1.40	0.00%
		Non-treatment	21.70%	5.33	17.25%	1.30	-20.50%
	Ship rat	Treatment	46.30%	7.70	25.30%	6.70	-42.40%
2001		Non-treatment	79.00%	5.90	75.00%	21.15	-5.00%
Cholecalciferol	Possum	Treatment	9.00%	3.48	4.00%	1.00	-58.00%
		Non-treatment	16.50%	3.88	17.50%	3.30	+6.00%

Cholecalciferol

The 3% target was not achieved for either pest species. Rat control results for the 2001 cholecalciferol trial contrasted dramatically with the previous trials, which used an anti-coagulant rodenticide. (See Table 1.) Ten rats were caught as a by-catch of possum indexing in the treatment area and thirteen rats in the non-treatment area. Two rats were caught as a by-catch of possum indexing in the treatment area and twelve in the non-treatment area. The pre-poison possum indices were unfortunately influenced by two nights of heavy showers and so are probably conservative.

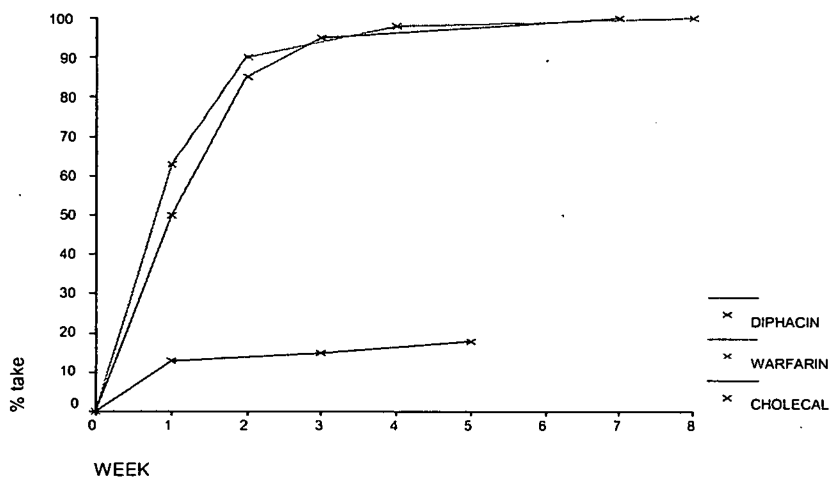
BAIT TAKE

Diphacinone

After five nights, cumulative bait take averaged 50% and after two weeks approximately 85% of bait had been eaten. After three weeks a total of approximately 95% of bait had been eaten. (See Figure 1.) Without extensive searching, an average of 2.4 dead possums per station was found after three weeks.

The last of the monitored bait was eaten seven weeks after it was applied

FIGURE 1. CUMULATIVE BAIT TAKE



and was still killing possums.

Approximately 130mm of rain fell on the trial area in the first two weeks after application but bait quality did not appear to be affected.

Warfarin

Bait take followed a similar pattern to the diphacinone trial with an average of 63% of bait taken in the first week, 90% taken by the second week and 100% taken by week eight.

Access to the raised stations did not appear to be a problem for possums or rats even when suitably sloping or forked trees were not chosen. Very few stations were pulled off the nails.

Cholecalciferol

By contrast, the same volume of rice-based paste containing 0.1% cholecalciferol was not consumed with the same vigour. Only 13.4% consumed in the first week, 15.5% by the third week and 17.5% by the fifth week.

Both possums and rats were detected by post-poison indexing within 20m of poison stations.

COSTS

Costs per hectare were assessed using the figures in Table 2.

TABLE 2. FIGURES USED TO DETERMINE COSTS PER HECTARE.

Materials for each station	**$**
Cardboard tube (1 @$0.20)	0.20
Cardboard discs (2 @$0.10)	0.20
Toxic paste (350g @$65.00/20kg)	1.10
Ferarox® (8 pellets @$0.44ea)	3.50
Subtotal	**5.00**

Total cost	**$**
Total costs of bait stations	1,000.00
Labour[1] to treat 100ha (4 days @ $ 115/day)	460.00
TOTAL COST OF TREATMENT	**1,460.00**

Cost per hectare	**$**
Stations (@ 2/ha)	10.00
Labour (@ 4 days @ 115/day/100)	4.60
TOTAL	**14.60**

10. Discussion

The use of Feratox® within anti-coagulant paste achieved rapid, potentially sustained and cost effective reduction of possums and rats from moderate densities. Cholecalciferol paste did not achieve the 3% target for either pest, and can probably be attributed to toxin-induced bait-shyness. Confidence in these results is limited by the low number of monitoring devices used, but compares very well to previous results and clearly illustrates that this approach is capable of a significant reduction in both target animals.

Confidence in these results, however, appears greater if a number of factors are taken into consideration. These are:

- the rat by-catch during possum indexing;
- the layout bias actively targeting areas of least exposure to poison; and
- the change in residual rates within the non-treatment area post-poison.

[1] Does not include labour costs of station construction.

The most "disappointing" result was the 5% residual rat index during the diphacinone trial in 1999. Two tunnels 150m apart were "tracked" out of 39 tunnels. This may have resulted from high numbers of possums in the vicinity removing bait before the rat(s) had adequate access to it. Therefore the effect on ship rats could be closely related to the pattern of bait removal by possums, as the bait take pattern during the 1999 trial showed a particularly high take from that area in the first five days. The three closest poison stations averaged 80% bait-take after four nights, compared with the overall average of 50%.

Anecdotally, there was a faster rate of bait take on the ridges than in gully sites and a higher number of possums killed at those stations. The rats that survived in these sites and were subsequently tracked may not have had adequate exposure to the bait due to possum competition. To counter this problem, additional stations could be placed along main ridges in order to alleviate high initial possum pressure on parts of the grid system.

Diphacinone, while being a first generation anti-coagulant, has been shown by one study (Bullard *et al.* 1976) to persist in a similar manner to brodifacoum and is not currently favoured by the Department. Less persistent anti-coagulants such as warfarin and pindone would be safer and more acceptable to the public and have proven to be effective.

During the 2000 warfarin trial, the omission of non-toxic pre-feed pellets within the paste appears to have seriously reduced the effectiveness of this operation on possums. Despite the reduced number of cyanide pellets used, the magnitude of operational failure suggests that this was not the primary cause of failure. It is more likely that cyanide pellets were not being crushed due to the omission of pre-feed pellets. Warfarin however, performed particularly well on rats, considering the large volume of bait effectively wasted by possums as a result of the lack of pre-feed pellets during that trial.

It is unfortunate that two variables were changed (toxin and base matrix) in the 2001 trial, either one of which could have resulted in a low bait take. However, the palatability of the rice paste was the subject of trial work by Feral Control who found it highly palatable to rats. This was supported by infra-red videography undertaken in Northland Conservancy, which suggested that lured rice paste was more attractive than peanut paste to both rats and possums. Because of this, it is more likely that the very low bait take and resultant operational failure was caused by the acute nature of the active rodenticide, leading to bait aversion in both ship rats and possums. Obviously bait aversion would only occur in those possums which did not bite a cyanide capsule before the onset of sub-lethal cholecalciferol-induced symptoms.

The apparent bait aversion issue arising from the 2001 cholecalciferol trial could possibly be reduced by incorporating an initial non-toxic pre-feed section in the bait station. This would simply be a matter of loading one quarter to one third of the station with toxic cholecalciferol paste first (the last section to be eaten) and the remainder with non-toxic paste and the majority of the cyanide capsules. This should have the effect of:

- reducing the amount of rodenticide consumed by non-target possums;
- reducing the chances of toxin induced bait shyness in possums and rats; and
- pre-feeding rats so that they are likely to consume more toxic paste once they get to it.

The high initial bait take in the first two trials indicates that the target animals readily found the raised and visually uninteresting (dull brown) stations. This removes the labour of pre-feeding and the visual impact of plastic or paper bait stations as well as placing the toxin out of the reach of most terrestrial non-target animals. If stations were laid out accurately off a temporary (or permanent) base line, the cutting and marking of poison lines and stations would not be required. A sample of stations can be monitored to assess bait take before re-opening treated areas. Such an approach would require Medical Officer of Health concurrence.

The attractiveness of bait presented in this manner to non-target species is not well known. Feral pigs have fed from this type of bait station during kokako nest protection, which led to stations being raised 1.5m off the ground. Kiwi call rates were unaffected during the 1998 trial when all bait was presented at ground level (R.Colbourne pers. comm.). Subsequently, captive kiwi and other native birds were offered non-toxic peanut butter. Some interest was shown, but none was consumed, even by juvenile kiwi (R. Webb pers. comm.). During the first trial, time lapse infra-red videography revealed a high number of ground dwelling beetles feeding on the paste - another reason to raise the stations. The paste matrix, however, is now based on rice not peanuts.

Bait quality was not an issue during the first two trials as all monitored bait was consumed within eight weeks of application. Mould began to grow on the exposed paste, especially in damper sites as bait take tapered off, but it remained palatable. Presumably the air and water-resistant packaging maintained the unexposed bait in a palatable condition.

A modification to the stations would allow them to be tied to trees with jute string or stapled to trees. This would improve the "eco-friendliness" of the system by removing the need for nails. At present, using low-tech manual loading, each station takes, with practice, a little over one minute to construct. Cost effectiveness can be improved by mechanising this station construction process. Feral Control Ltd has indicated some interest in mechanising this system (Steve Boot pers. comm.).

The option of aerial application of stations such as these is worthy of some discussion. Currently only 1080 can be applied from the air and only as pollard or carrot baits thinly applied over forest. This is despite the fact that 1080 is often perceived negatively by the public, and cyanide is perceived as being relatively safe. Cyanide, in various forms, is applied by hand at ground level throughout the country, without any major non-target issues arising from its use. While there may be justification for further study of non-target effects, it seems illogical that 1080 can be applied aerially but not cyanide or cholecalciferol.

The two-stage station delivering cyanide via a non-toxic paste before the toxic (i.e. cholecalciferol) paste needs to be developed further and may be the subject of further trial work.

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